GEOCHEMISTRY AND FLUVIAL GEOMORPHOLOGY REPORT

A DRAFT REPORT TO THE GRANT-KOHRS RANCH NATIONAL HISTORIC SITE

JANUARY 28, 2002

BY

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AND
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SUMMARY

Maps of the concentration and multiples of baseline (as determined from soil profiles analyzed in the 2000 geochemistry study) in megaplot sample sites for As, Cd, Cu, Pb, Zn and pH do not show any particular spatial trends. However, all values are substantially above baseline concentrations. Only one site for arsenic and eight sites for cadmium are below 5 times the baseline concentrations. All other sites have concentrations of Cu, Pb and Zn more than five times the baseline concentrations. Copper is by far the highest elevated over baseline, with median values of about 170 times baseline and ranging up to about 445 times baseline concentration. Cadmium has the lowest values, about 10 times baseline concentrations for most sites. Arsenic, Pb and Zn were similar with mean values of generally in the 20 to 35 times baseline. Concentrations of metals and arsenic in the megaplots sites are comparable to those found in the floodplain/riparian area during the 2000 surface soil sampling. Visual and statistical comparisons show that possibly only Cd and Zn may be slightly higher in the 2001 dataset compared to the 2000 dataset. The megaplot soils have a wide range in contamination levels, similar to those found in the same areas in the 2000 surface soil geochemistry data.

In the upland soil areas, vertical trends in metals and pH indicate that contaminants were added to the upland soils from air-fall. Contaminants are still mostly concentrated in the upper 5-10 cm of the soils. Some elements show more mobility at certain sites, indicating that some metals and acid have moved to depths of from 20-50 cm. Contaminants are concentrated from about 3-5 times over reference values found deeper in the soil column. Profiles at five of the six sites sampled have the highest elemental concentrations and the lowest ph in the upper c.a. 5-10 cm. This trend is most obvious for As and Cu, but other elements show this increase as well. This distribution can be best explained by addition of contaminants (metals, arsenic, and sulfur oxide compounds from air-fall into the soils. The surface interval showed distinct elevation above reference values found at depth. There is about 4 1/2 times as much arsenic in the surface soils as would be expected if air-fall did not occur. Similar contamination indices are seen for other elements.

Comparing BLM tract sites to Grant-Kohrs Ranch Megaplots sites shows that metal and arsenic concentrations are generally lower in the BLM tracts. Although concentrations of metals and arsenic are lower in the soils of the BLM tracts, BLM tracts have metal and

arsenic concentrations elevated above the baseline values found at Grant-Kohrs Ranch. Copper is the element most elevated at all the sites and occurs at multiples of baseline much higher than the other elements. The other elements follow in the order Zn > As > Pb > Cd.

There are several conclusions that can be made from the observations made on channel and floodplain morphology. First, there is a large amount of channel migration. The outside of meanders are eroding at approximately 0.5 meters/year. This results in about 3.0 acres of floodplain being removed each year. At these rates, it will take around 800 years to rework the Grant-Kohrs Ranch floodplain (and the tailings deposited there) once. This erosion is approximately balanced by the deposition of new material on the point bars, so that there is no measurable net loss of land. However, the land along the river meander belt is definitely transformed. The position of eroding banks is controlled dominantly by the morphology of the river channel. The coincidence of riffles on meander bends are associated with the largest amount of bank erosion and cutbank formation. The presence of vegetation and tailings thickness seem to have very little affect on the position and amount of erosion. Cutbank formation appears to be a combination of undercutting of the bank by high flows and the slumping of material into the channel. The unconsolidated/non-cohesive gravel and pre-mining floodplain deposits at the base of the banks are easily eroded, leaving overhangs that can slump/cave into the river channel. It will be very difficult to stabilize the banks unless the erosion of these lower levels can be slowed. Presently, it appears that the banks are unstable because of the lack of deep-penetrating roots into the lower layers. The deposition of tailings on the floodplain has elevated the floodplain surface, exacerbating the effects from metals loading and preventing deep rooted plants from reaching moisture and stabilizing the lower levels of the banks. Vegetation cover and slicken size appear to be mostly controlled by moisture. The major dimension of slickens are relatively stable from 1947-2001. However, vegetation cover definitely changes over time in response to wetter or dyer conditions. During dry years, woody vegetation is senescent/dead in slicken areas but grows again during wet years. Many areas that are bare slickens in the dry years appear to be covered with grass when moisture increases. These observations show that the slickens are very dynamic and will change due to forcing by climatic conditions. The floodplain system is dynamic and rapidly changing. The rate of channel migration and vegetation cover is controlled by river flow and precipitation.

CHAPTER I

CHEMICAL CONCENTRATIONS IN SURFACE SOILS OF THE MEGAPLOTS AT GRANT–KOHRS RANCH NATIONAL HISTORIC SITE

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INTRODUCTION

Soil microbial respiration, microbial community studies and plant toxicity studies were conducted at sites termed “megaplots” throughout the riparian zone of Grant–Kohrs Ranch in the summer of 2001. Associated with those biological studies, the concentrations of metals and organic carbon, as well as pH, were determined at each of the sites. The results of those analyses are reported in this data report and compared to values determined in 2000 at the same locations.

METHODS

Samples were collected from thirty megaplots distributed throughout the floodplain/riparian area in Grant-Kohrs Ranch. These sites were selected by the biologists based on data collected in 2000 (see microbiology report by Gannon, et al, 2001). The sites are widely distributed throughout the floodplain/riparian area (Figure I-1).

The geochemistry of the megaplot soils was determined by compositing soil samples from the upper 6 inches of the soil profile (to coincide with the soil respiration measurements made by the microbiologists). Four surface soil samples were collected using a soil hand auger (see SOP SS-1). The four sub-samples were homogenized to prepare a single composite sample. The samples were stored and transported to the laboratory for sample preparation and analysis. Samples were transported to the laboratory following chain-of-custody procedures as per the QAP and SOPs QA-7, QA-8, QA-9, and QA-10. Upon laboratory receipt, samples were split into three portions as per SOP SS-13. For total metals analysis, each subsample was dried and ground to ensure sample homogeneity (see SOP SS-3). They were transferred to labeled and sealed plastic containers (e.g. snap-cap vials) and stored in a secure area until digestion. Samples were digested as per a modified EPA Method 3050B (see SOP EPA 3050B) for the extraction of total metals. Digests were analyzed for total metals by ICAP-ES as per modified EPA Method 200.7 (see SOP EPA 200.7). Elements of concern include arsenic, cadmium, copper, lead, and zinc. Organic carbon was determined by SOP SS-12.

RESULTS

GENERAL TRENDS AND COMPARISONS

The detailed data for the thirty megaplot soil sites is presented in Appendix I-A. An overview of the average values found and relationships to 2001 data are presented here. The concentrations of metals and arsenic in the megaplot soils had a wide range. Arsenic ranged from a low of 32 ppm to a high of 880 ppm, with a mean of 361 ppm (Table I-1). The mean concentration of cadmium at all the sites was 7.2 ppm with a range from 3.2 ppm to 16 ppm. Copper ranged from a low of 600 ppm to a high of 7100 ppm, with a mean of 2579 ppm. The average concentration of lead was 381 ppm, with a low of 110 and a high of 1100. Zinc had a mean concentration of 1592 ppm with a low of 720 ppm and a high of 2900. The mean pH for all the samples was 6.7 with a range from 4.2 to 8.2. Organic carbon averaged 4.4% but ranged from a low of 0.9% to 14.6%.

TABLE I-1 Descriptive Statistics of Megaplot Soil Samples.

	Mean	Std. Dev.	Number	Minimum	Maximum
As (ppm)	361	224	30	32	880
Cd (ppm)	7.2	3.1	30	3.2	16
Cu (ppm)	2579	1633	30	600	7100
Pb (ppm)	381	212	30	110	1100
Zn (ppm)	1592	563	30	720	2900
pH	6.7	1.0	30	4.2	8.2
Org. C (%)	4.4	3.1	30	0.9	14.6

Samples collected in 2001 for the megaplot sites had very similar concentrations of metals and pH values to those collected in 2000 from the same sites (surface soils, designated "SS" in 2000). The 2000 samples were collected from the upper 12 inches of the soil profile instead of the 6 inches for the 2001 samples (see microbiology report by Gannon, et al, 2001). Only one augered sample was taken at each site in 2000, instead of the four augered samples composited into one sample in 2001. However, when examining the descriptive statistics for the two sample sets, even though the samples were collected somewhat differently, the values are quite similar (Table I-2). In general the means for all constituents appear slightly higher in 2001 data than in the 2000 data.

Z-Score Histograms of the data show that most of the constituents are not normally distributed (Figure I-2). Therefore comparisons of the two years by T-Test was not appropriate. Instead, a non-Parametric statistical comparison (Wilcoxian Signed Rank Test) was used to compare 2000 data with 2001 data. This test is based on the differences between each pair of data and tests the hypothesis that the sum of the ranks is equal to zero under the assumption that the distribution of ranks is symmetric around zero.

The results of these statistical tests show that there is no significant difference between values of As, Cu, Pb, and pH between 2000 and 2001 (the p-values are high and the mean ranks and sum ranks are similar). Cadmium was the only constituent that showed a significant difference between the two years (p-value of <0.0001). Zinc was possibly different between years (p-value of 0.0898).

In general, the data shows that there is only minor differences between the data collected in 2000 (12 inch depth) compared to that collected in 2001 (6 inch depth). Concentrations are essentially the same for most elements measured (except Cd and possibly Zn) and pH. These statistical relationships are visible in box plots of the data (Figure I-3). All data from 2000 overlaps with data from 2001 except for small differences in the medians for cadmium and zinc between years.

TABLE I-2 Comparison of Chemical Data for Megaplot Soil Samples in 2000 and 2001.

	Mean	Std. Dev.	Number	Minimum	Maximum
As (ppm) - 2000	340	248	30	47	940
As (ppm) - 2001	361	224	30	32	880
Cd (ppm) -2000	5.2	2.8	30	0.9	12
Cd (ppm) - 2001	7.2	3.1	30	3.2	16
Cu (ppm) - 2000	2258	1448	30	420	5400
Cu (ppm) - 2001	2579	1632	30	600	7100
Pb (ppm) - 2000	349	205	30	74	920
Pb (ppm) - 2001	381	212	30	110	1100
Zn (ppm) - 2000	1450	707	30	320	3200
Zn (ppm) - 2001	1592	563	30	720	2900
pH - 2000	6.52	1.12	30	4.26	8.00
pH - 2001	6.69	1.02	30	4.23	8.25

Distribution of Constituents and Comparison to Baseline

Figure I-1 shows the distribution of megaplot sample sites. Maps of the concentration and multiples of baseline (as determined from soil profiles analyzed in the 2000 geochemistry study) for As, Cd, Cu, Pb, Zn and pH are presented in Figures I-5 to Figure I-15. The concentration and multiples of baseline data do not show any particular spatial trends. However, all values are substantially above baseline concentrations (As = 10 ppm; Cd = 1 ppm, Cu = 17 ppm; Zn = 49 ppm). Only one site for arsenic and eight sites for cadmium are below 5 times the baseline concentrations. All other sites have concentrations of Cu, Pb and Zn more than five times the baseline concentrations. Copper is by far the highest elevated over baseline concentrations as can be seen in the boxplot of baseline multiples (Figure I-4), with median values of about 170 times baseline and ranging up to about 445 times baseline concentration. Cadmium has the lowest values, about 10 times baseline concentrations for most sites. Arsenic, Pb and Zn were similar with mean values of generally in the 20 to 35 times baseline (Table I-3).

TABLE I-3 Descriptive Statistics of Multiples of Baseline Data for the Megaplot Soil Samples.

	Mean	Std. Dev.	Number	Minimum	Maximum
As (times baseline)	36	22	30	3	88
Cd (times baseline)	7	3	30	3	16
Cu (times baseline)	161	102	30	38	444
Pb (times baseline)	22	12	30	6	65
Zn (times baseline)	32	11	30	15	59

Conclusions

Concentrations of metals and arsenic in the megaplots sites are comparable to those found in the floodplain/riparian area during the 2000 surface soil sampling. Visual and statistical comparisons show that possibly only Cd and Zn may be slightly higher in the 2001 dataset compared to the 2000 dataset. The megaplot soils have a wide range in contamination levels (multiples of baseline concentrations) and similar to those found in the same areas in the 2000 surface soil geochemistry data.

CHAPTER I-FIGURES

CHEMICAL CONCENTRATIONS IN SURFACE SOILS OF THE MEGAPLOTS AT GRANT–KOHRS RANCH NATIONAL HISTORIC SITE

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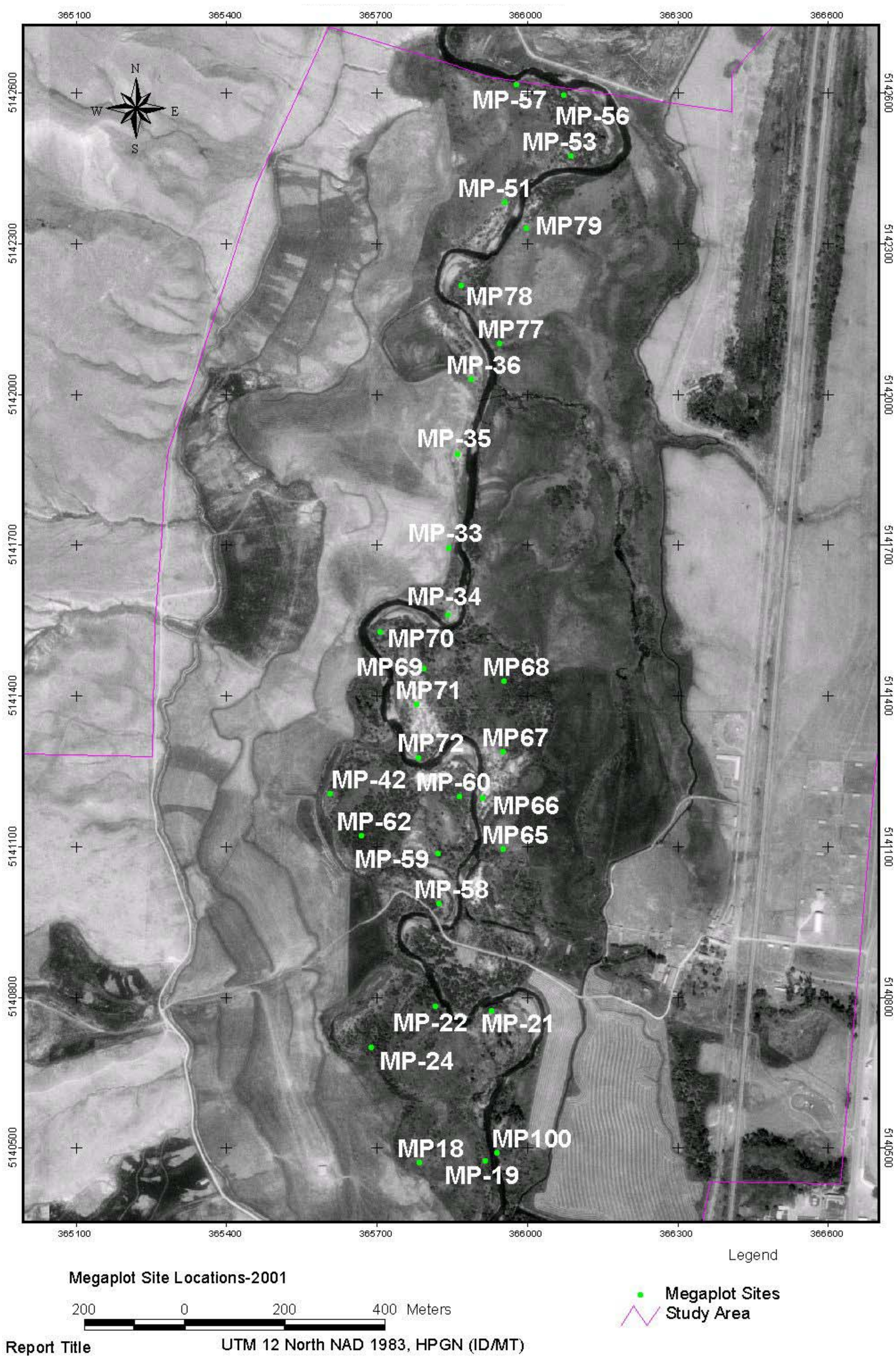
Figure I-1



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MP-42
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MP-62
MP65
MP-59
MP-58
MP-22
MP-21
MP-24
MP18
MP100
MP-19
Legend
Megaplot Site Locations-2001
200 0 200 400 Meters
Megaplot Sites
Study Area
Report Title
UTM 12 North NAD 1983, HPGN (ID/MT)

Figure I-2

Figure I-2 Z-Histograms of the Geochemical Data for 2000 and 2001.
Z-values are number of standard deviations from the mean value, set at zero.

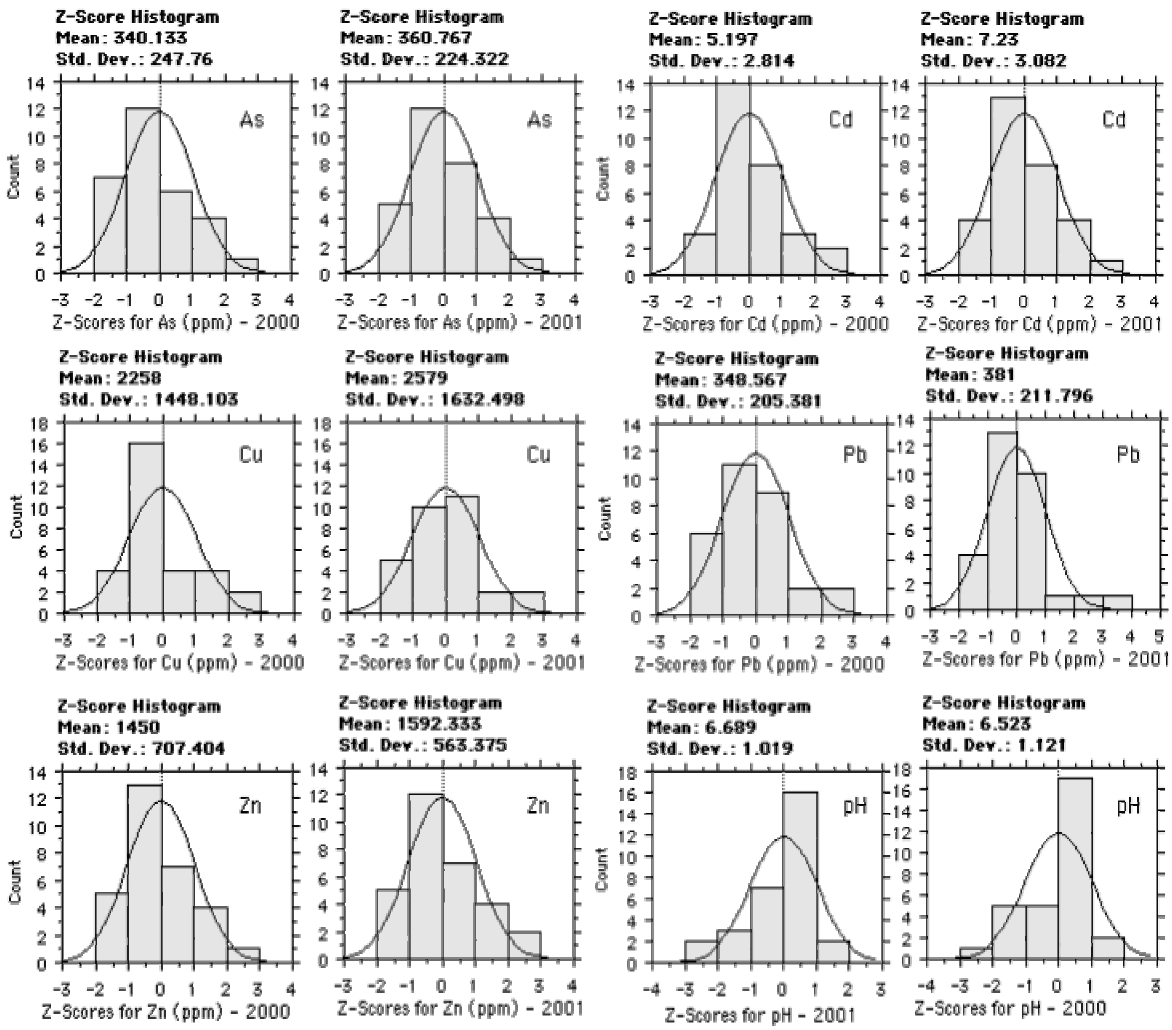


Figure I-3

Figure I-3 Box Plot of Geochemical Data for 2000 and 2001. The top of the box represents the 75th percentile value, and the bottom of the box the 25th percentile value. The horizontal line represents the median value. The whiskers above and below the box represent the 95th and 5th percentile values; the small circles are data lying outside that range.

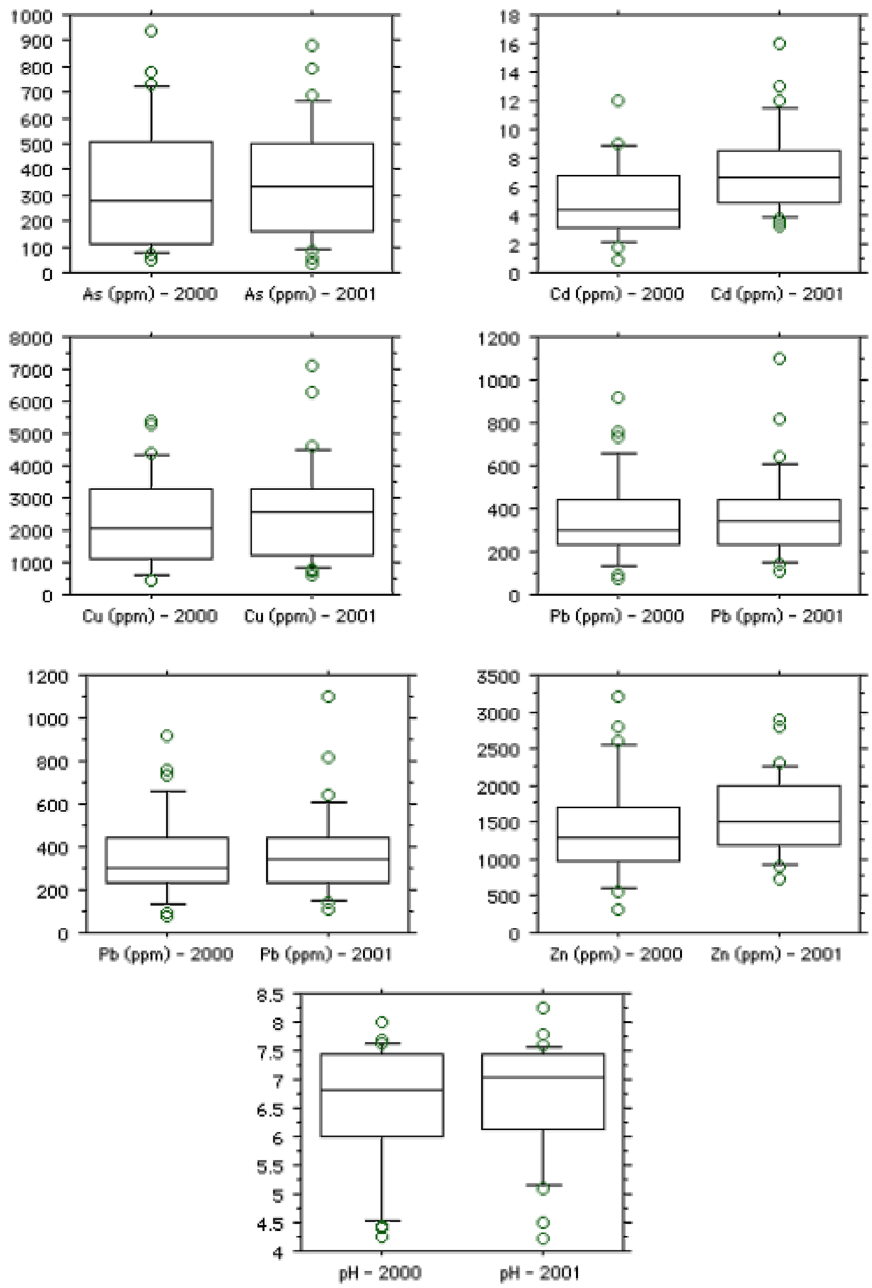


Figure I-4

Figure I-4 Box plots of multiples of baseline concentration for megaplot sites.

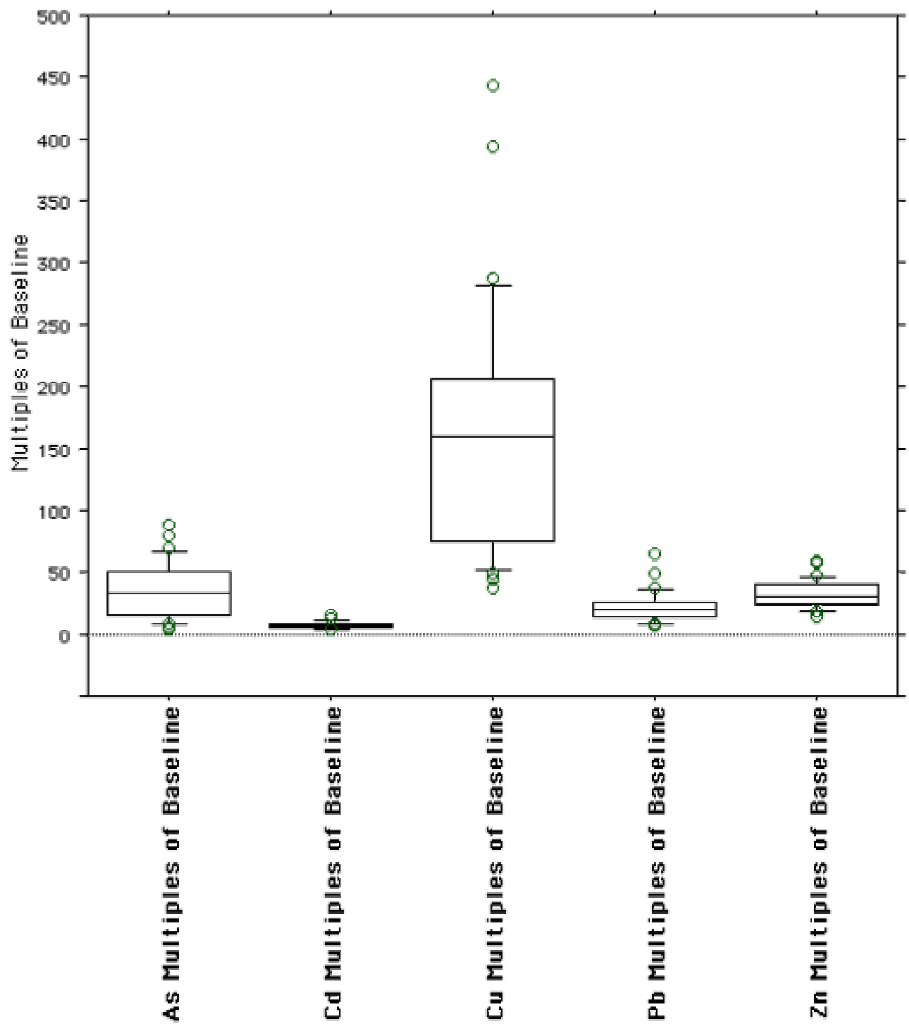
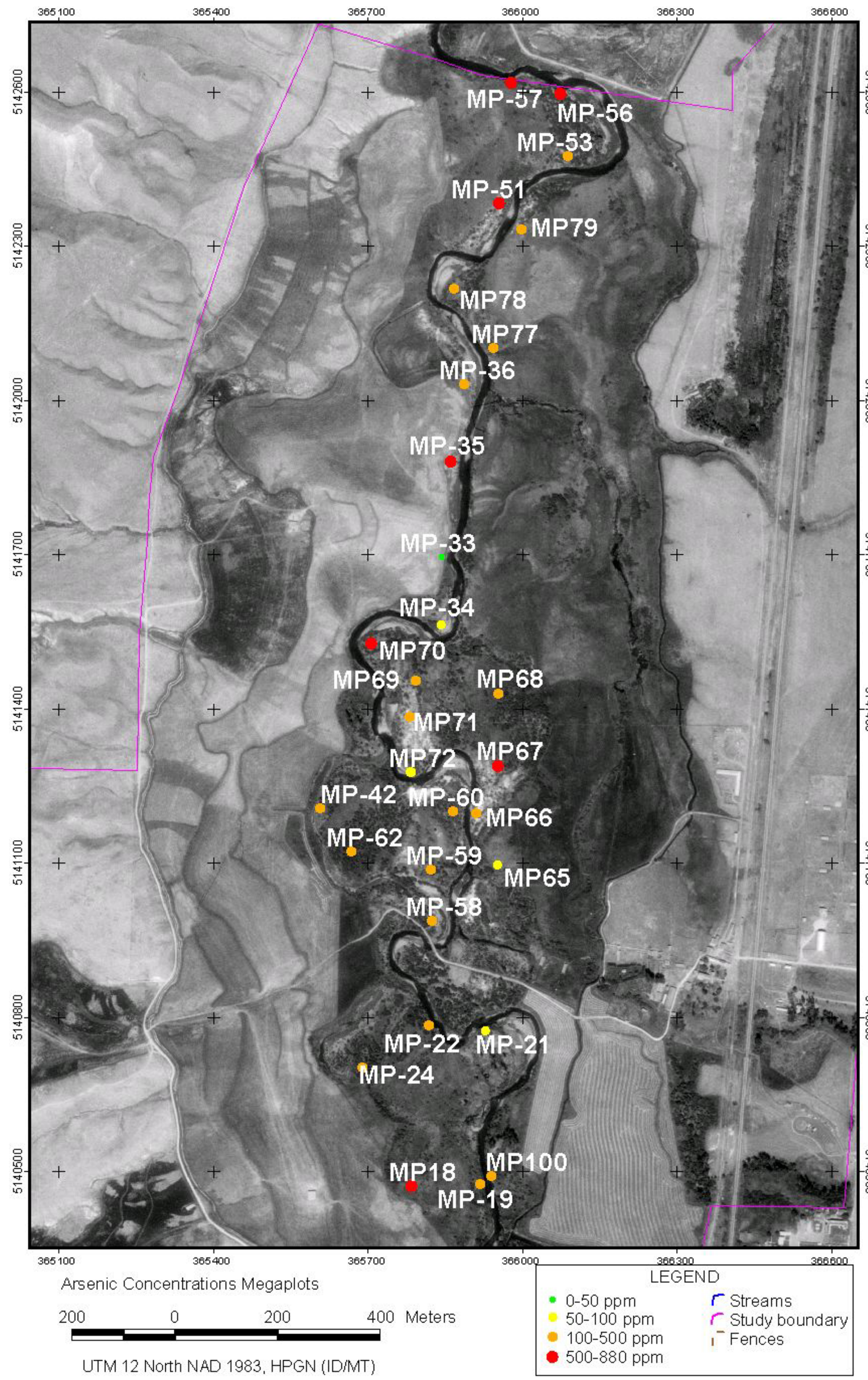


Figure I-5



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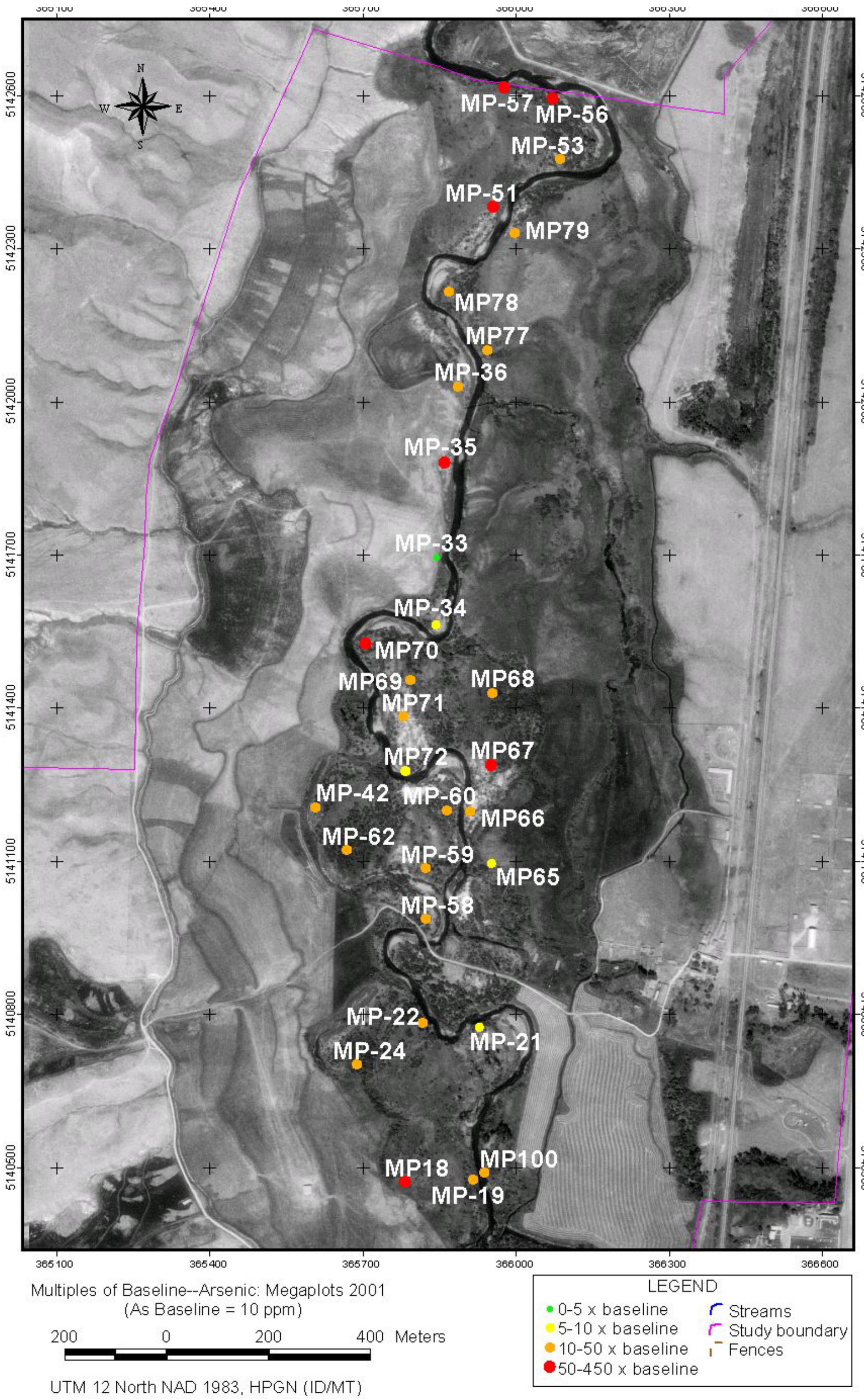
MP-42
MP-60
MP66
MP-62
MP-59
MP65
MP-58
MP-22
MP-21
MP-24
MP18
MP100
MP-19
Arsenic Concentrations Megaplots
200 0 200 400 Meters
UTM 12 North NAD 1983, HPGN (ID/MT)
LEGEND
0-50 ppm
50-100 ppm
100-500 ppm
500-880 ppm
Streams
Study boundary
Fences

Figure I-6



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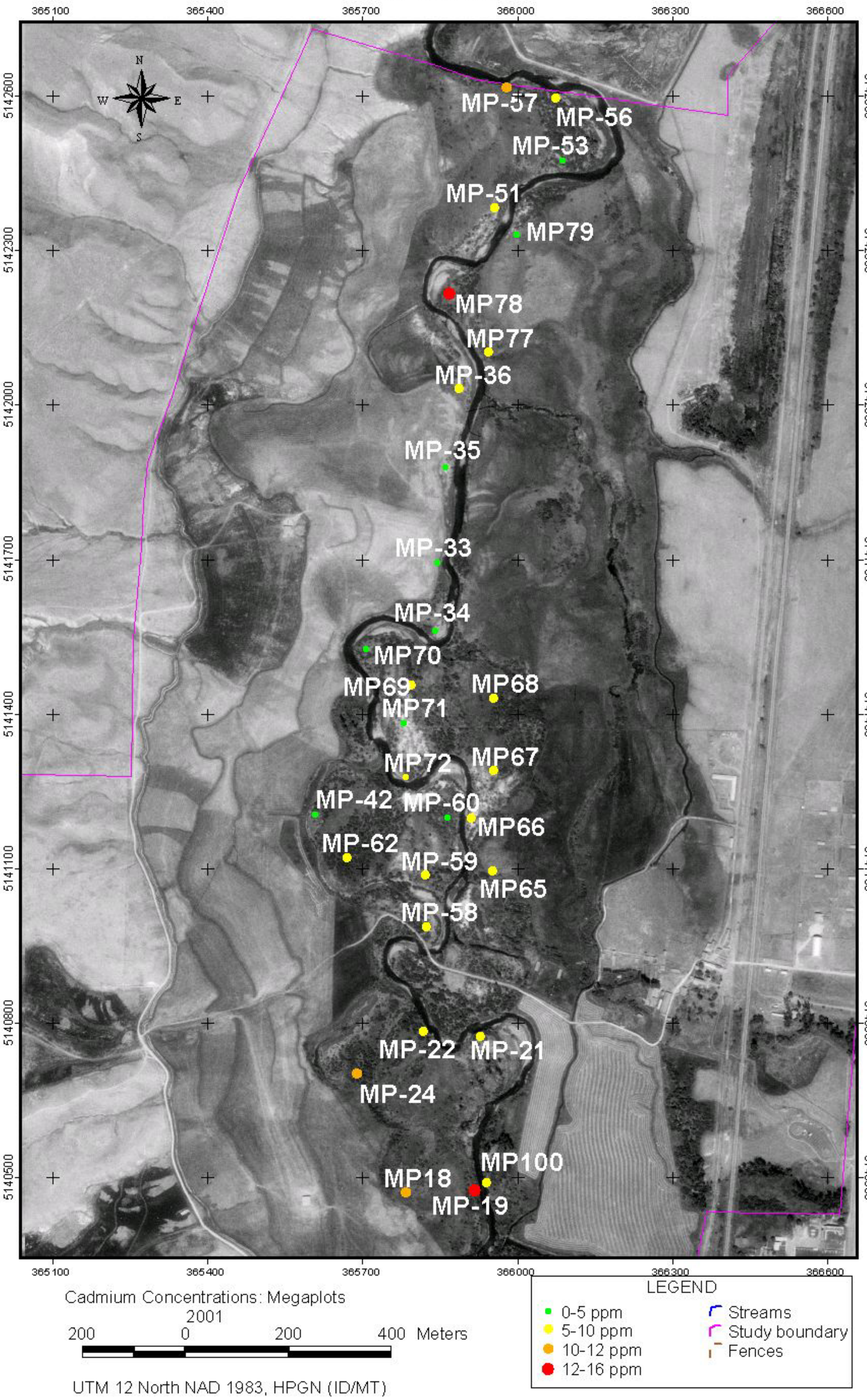
MP-62
MP-59
MP65
MP-58
MP-22
MP-21
MP-24
MP18
MP100
MP-19
Multiples of Baseline--Arsenic: Megaplots 2001
(As Baseline = 10 ppm)
200 0 200 400 Meters
UTM 12 North NAD 1983, HPGN (ID/MT)
LEGEND
0-5 x baseline
5-10 x baseline
10-50 x baseline
50-450 x baseline
Streams
Study boundary
Fences

Figure I-7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MP66
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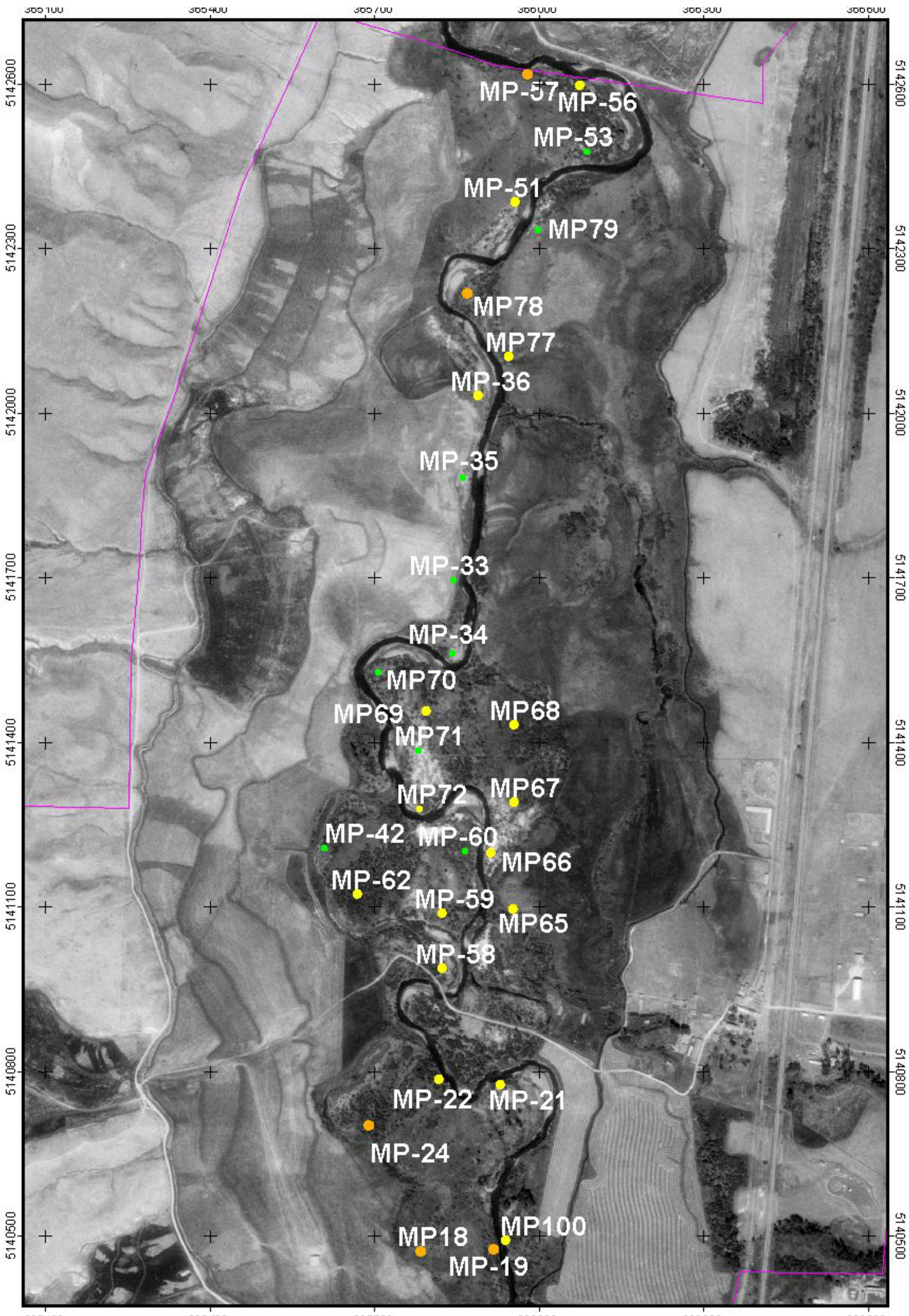
MP-59
MP65
MP-58
MP-22
MP-21
MP-24
MP100
MP18
MP-19
Cadmium Concentrations: Megaplots
2001
200 0 200 400 Meters
UTM 12 North NAD 1983, HPGN (ID/MT)
LEGEND
0-5 ppm
5-10 ppm
10-12 ppm
12-16 ppm
Streams
Study boundary
Fences

Figure I-8



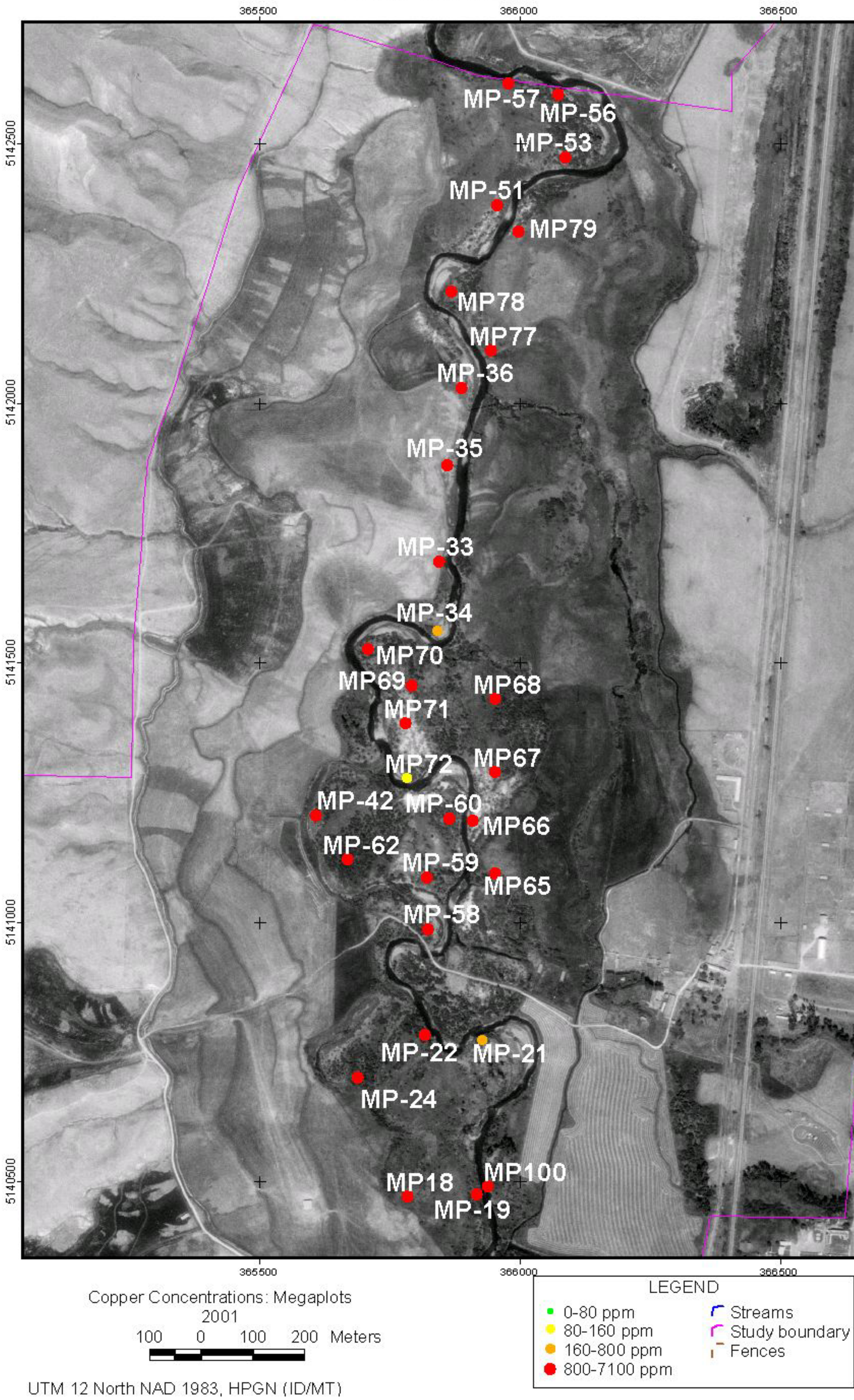
Multiples of Baseline--Cadmium: Megaplots 2001
(Cd baseline = 1 ppm)

200 0 200 400 Meters

UTM 12 North NAD 1983, HPGN (ID/MT)

LEGEND
- 0-5 x baseline
- 5-10 x baseline
- 10-50 x baseline
- 50-450 x baseline
- Streams
- Study boundary
- Fences

Figure I-9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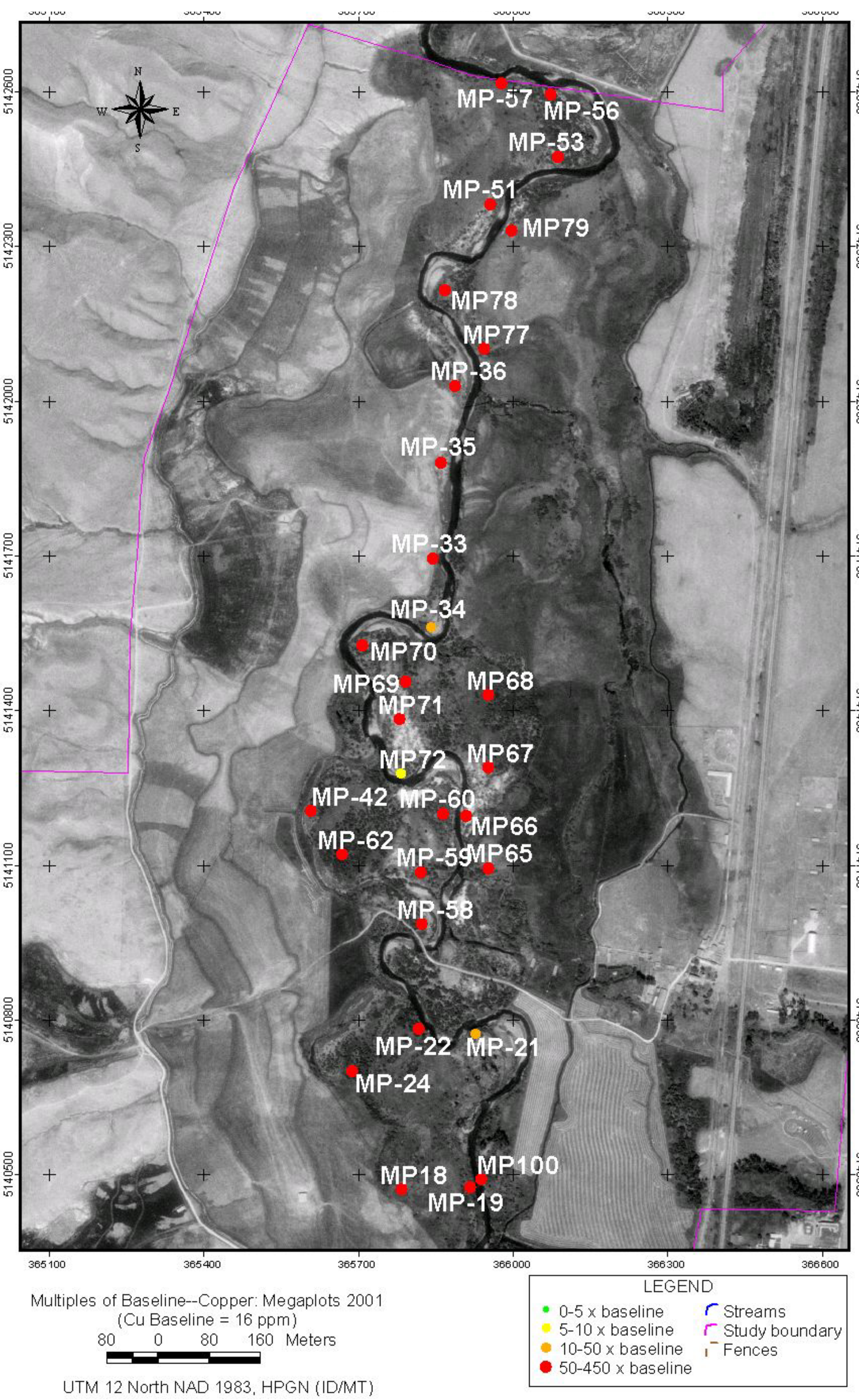
MP-42
MP-60
MP66
MP-62
MP-59
MP65
MP-58
MP-22
MP-21
MP-24
MP18
MP100
MP-19
Copper Concentrations: Megaplots
2001
100 0 100 200 Meters
UTM 12 North NAD 1983, HPGN (ID/MT)
LEGEND
0-80 ppm
80-160 ppm
160-800 ppm
800-7100 ppm
Streams
Study boundary
Fences

Figure I-10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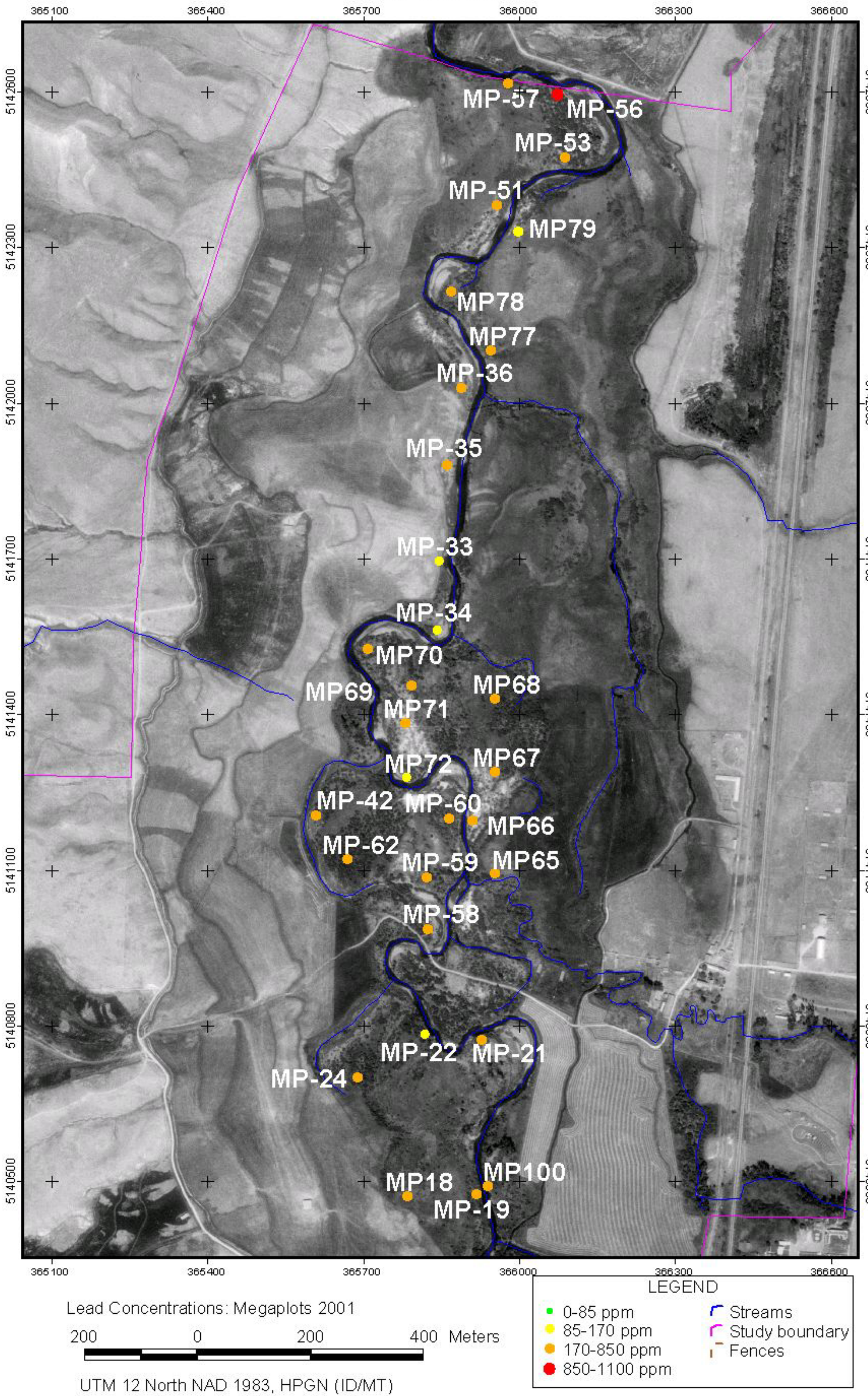
5141400
5141100
5140800
5140500
365100
365400
365700
366000
366300
366600
LEGEND
0-5 x baseline
5-10 x baseline
10-50 x baseline
50-450 x baseline
Streams
Study boundary
Fences
Multiples of Baseline--Copper: Megaplots 2001
(Cu Baseline = 16 ppm)
80 0 80 160 Meters
UTM 12 North NAD 1983, HPGN (ID/MT)

Figure I-11



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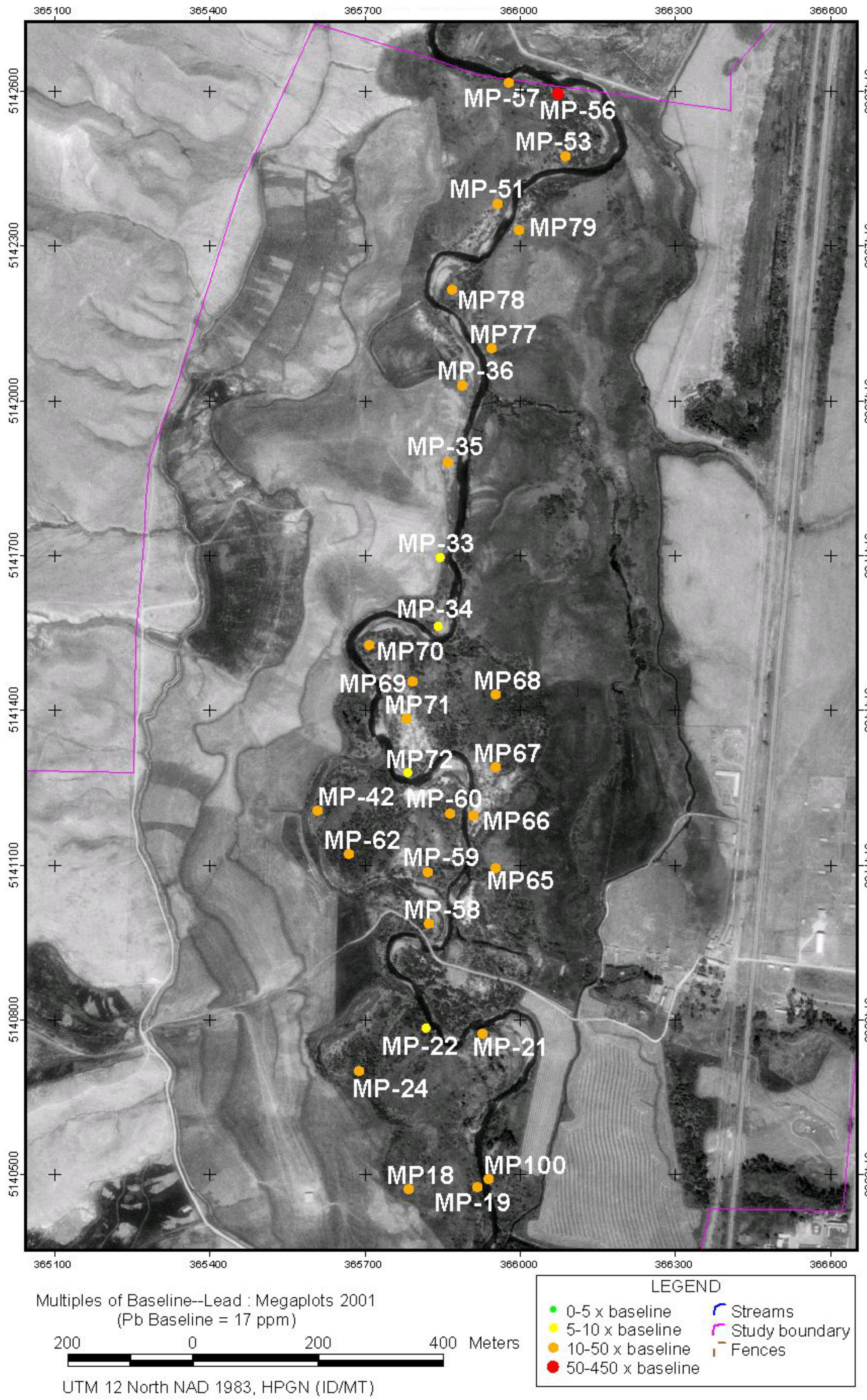
MP100
MP-19
Lead Concentrations: Megaplots 2001
200 0 200 400 Meters
UTM 12 North NAD 1983, HPGN (ID/MT)
LEGEND
0-85 ppm
85-170 ppm
170-850 ppm
850-1100 ppm
Streams
Study boundary
Fences

Figure I-12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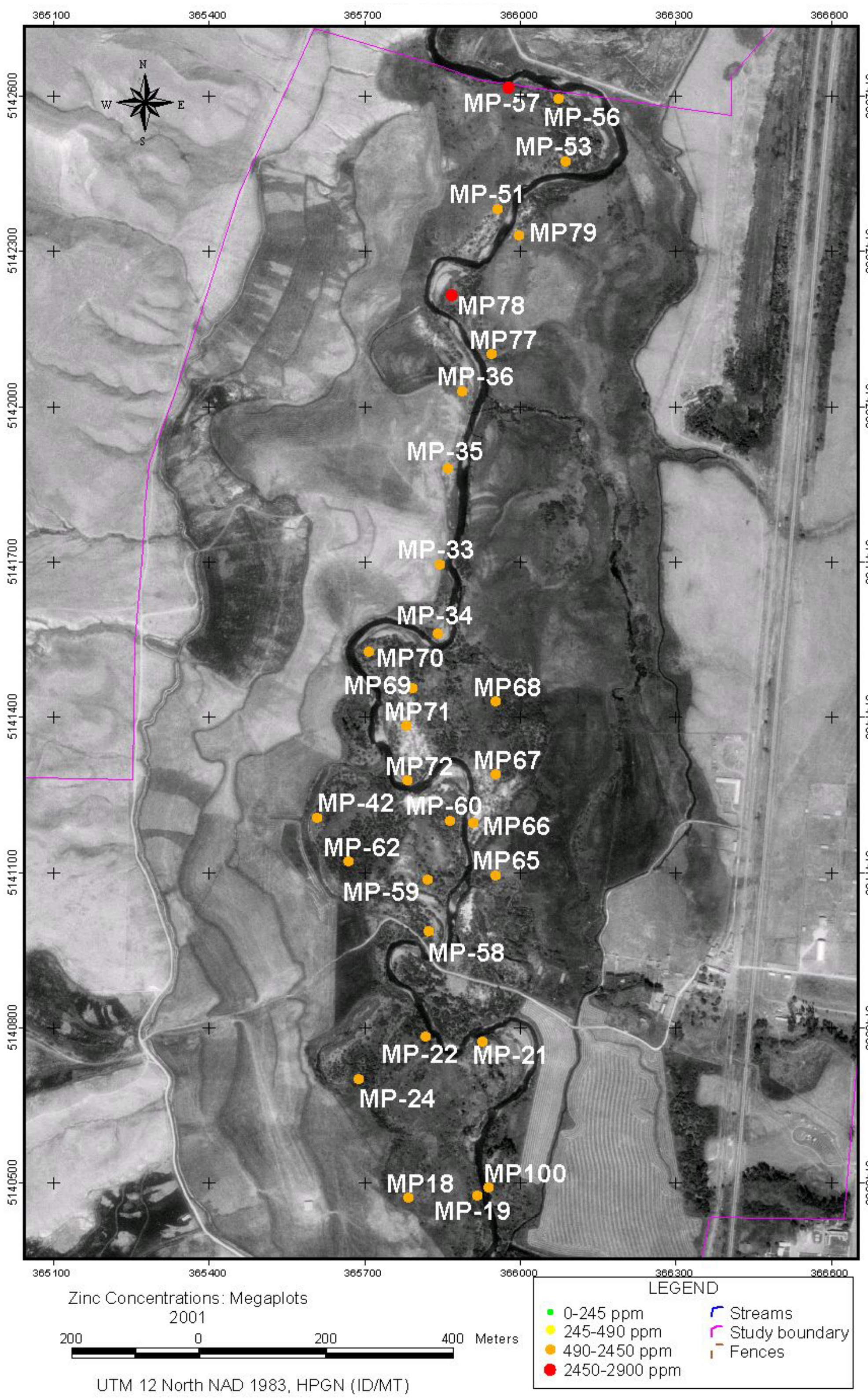
MP100
MP-19
Multiples of Baseline--Lead : Megaplots 2001
(Pb Baseline = 17 ppm)
200 0 200 400 Meters
UTM 12 North NAD 1983, HPGN (ID/MT)
LEGEND
0-5 x baseline
5-10 x baseline
10-50 x baseline
50-450 x baseline
Streams
Study boundary
Fences

Figure I-13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MP-21
MP-24
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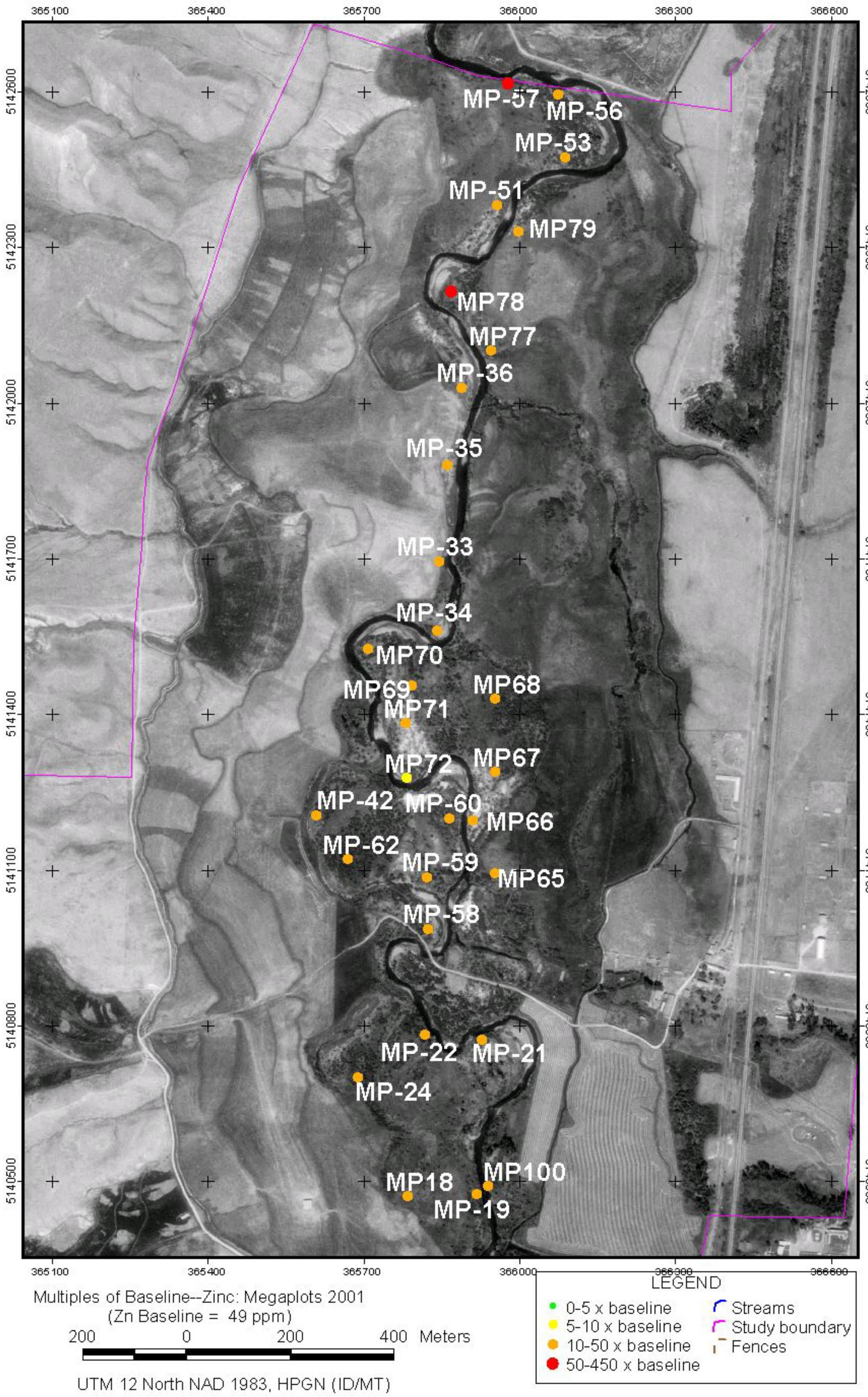
MP100
MP-19
Zinc Concentrations: Megaplots
2001
200 0 200 400 Meters
UTM 12 North NAD 1983, HPGN (ID/MT)
LEGEND
0-245 ppm
245-490 ppm
490-2450 ppm
2450-2900 ppm
Streams
Study boundary
Fences

Figure I-14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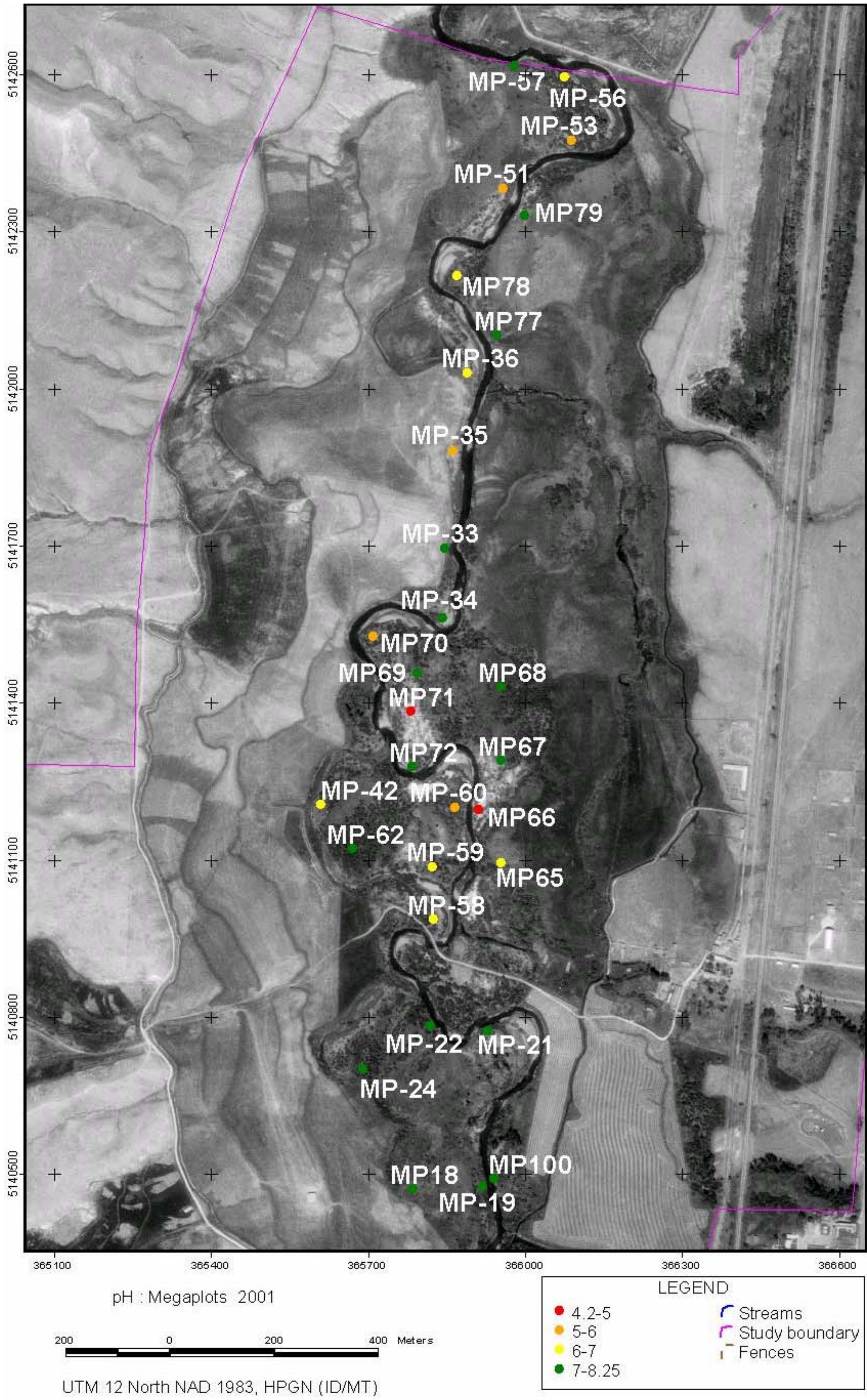
MP-58
MP-22
MP-21
MP-24
MP18
MP100
MP-19
Multiples of Baseline--Zinc: Megaplots 2001
(Zn Baseline = 49 ppm)
200 0 200 400 Meters
UTM 12 North NAD 1983, HPGN (ID/MT)
LEGEND
0-5 x baseline
5-10 x baseline
10-50 x baseline
50-450 x baseline
Streams
Study boundary
Fences

Figure I-15



MP-57
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MP-51
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MP77
MP-36
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MP-33
MP-34
MP70
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MP68
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MP67
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pH : Megaplots 2001
200 0 200 400 Meters
UTM 12 North NAD 1983, HPGN (ID/MT)
LEGEND
4.2-5
5-6
6-7
7-8.25
Streams
Study boundary
Fences

CHAPTER II

CHEMICAL CONCENTRATIONS IN VERTICAL PROFILES OF UPLAND SOILS AT GRANT–KOHRS RANCH NATIONAL HISTORIC SITE

GEOCHEMISTRY AND FLUVIAL GEOMORPHOLOGY REPORT

A DRAFT REPORT TO THE GRANT-KOHRS RANCH NATIONAL HISTORIC SITE

JANUARY 28, 2002

BY

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INTRODUCTION

Smelting of base-metal ores at Anaconda, Montana, spread air-fall contamination within the Deer Lodge Valley. After production began in the smelter in 1902, outbreaks of arsenic poisoning occurred in cattle, sheep and horses over an area of 260 km^2 (1) in the Deer Lodge Valley. One ranch, 20 km downwind from the smelter, lost 1000 cattle, 800 sheep and 20 horses during the first year of smelter operation. Construction of a flue system settled solids in the smoke but large contaminant releases continued: 27,000 kg/day arsenic; 2300 kg/day copper; 2200 kg/day lead; 2500 kg/day zinc (1). These contaminants accumulated in the soils around the smelter and continued to effect agricultural productivity long after the early days of smelting (2, 3). Even 60 km from the smelter, cadmium contamination was reported in soils, grain, cattle and swine (4). Soil contamination from the smelter may cover an area of at least 300 km^2 (5). The widespread distribution of this air-fall contamination makes it possible that arsenic and metals have accumulated in the soils of the Grant–Kohrs Ranch National Historic Site (GRKO) from air-fall deposition. However, detailed mapping of the distribution of contaminated soils is not available to determine the extent and magnitude of this contamination on GRKO lands. To address these issues we determined the concentrations of metals and arsenic in upland soil profiles at GRKO.

METHODS

Sampling sites were located in the upland areas of Grant–Kohrs Ranch. Upland areas were used to ensure that soils were not affected by irrigation with Clark Fork River water. Irrigated lands could potentially have received metal-contaminated sediment carried in irrigation flows. Six sites were located in upland areas that had not received irrigation and have been used only as upland pasture or are not grazed at all (Figure II-1). It is also likely that none of the sites have been tilled or otherwise modified (GRKO staff, personal communication). Because some of the areas are on relatively steep slopes, surface processes may have removed some surface soil in the past. However, no obvious soil erosion was present at the sites when sampled in the summer of 2001.

At the selected sites, gloved personnel used a round shovel to open a soil pit, with care taken to preserve the topsoil for proper restoration after sampling. Pit diameters were from 50 cm to 70 cm and the depth approximately 60 cm to accommodate sampling to a depth of 50 cm. One side of the pit was smoothed with a stainless steel trowel to remove any contamination from the excavation and so that the soil profile was visible. The sequence was then described (recording information on texture, color and structure) and photographed with a measuring tape for a scale. The surface was then cleaned with plastic utensils to remove any potential contamination from the excavation process. Samples were then taken from six intervals within the sequence: 0-5, 5-10, 10-20, 20-30, 30-40, and 40-50 cm. The basic sample was a 5 by 10 cm square in the upper two intervals and a 10 by 10 cm square in the lower intervals, 1 cm thick for a total volume of approximately 100 cc. Each sample was taken by scraping an outlined square portion of profile directly into a plastic bag with a clean plastic knife. The sampler donned clean gloves before each sample. Initial samples were taken at the very bottom of the profile, incrementally working upward through the profile with each sample, in order to keep from contaminating the profiles with debris from above. Samples were homogenized and sub-sampled for chemical analysis for As, Cd, Cu, Pb, and Zn. pH was also measured on a sub-sample from each interval. Sampling and analyses ethods are described in the Sampling and Analysis Plan (Appendix III).

Arsenic, metals and pH concentrations were plotted vs. depth for each profile (see Chapter II Figures). Because each interval was homogenized, the concentration is averaged over the entire interval sampled. When data were below the PQL (practical quantification limit), one-half of the PQL was used for plotting purposes. PQL levels used are: 10 ppm for As, 1 ppm for Cd, 6 ppm for Cu, 8 ppm for Pb and 16 ppm for Zn. The trends seen in these plots are summarized below.

RESULTS

Site F-1: The uppermost 10 cm of the soil profile at Site F-1 is elevated above lower sections for As, Cd, Cu, Pb and Zn (Figure II-2). The pH is also lower in the upper 10 cm. All the elements measured show higher concentrations in the surface layers and then decrease to constant values at depth. Arsenic shows a somewhat deeper penetration with values elevated above lower levels down to 20 cm. The upper 10 cm contained As values of 60 ppm. From 10-20 cm concentrations decreased to 20 ppm. Below 20 cm all the intervals were below 10 ppm (<PQL). Cd values were from 1.5 to 2.6 in the upper 10 cm and decreased to less than 1 ppm below that interval (<PQL). Cu concentration is from 120-140 in the upper 10 cm and drops to 15 ppm below 10 cm. Pb is from 40-60 ppm in the upper 10 cm and drops to about 18 ppm below. Zn shows a similar trend with the highest values in the upper 10 cm of 130-140 ppm and dropping to about 50 ppm below that interval. The soil profile at F-1 is also more acidic at the surface. From 0-10 cm the pH is about 5.5-5.9. Below this level the pH increases to about 7.

Site F-2: All elemental concentrations at this site were the lowest of all the sites. This section was also much more coarse grained than the others, containing gravel and cobbles throughout the profile. Arsenic and cadmium were below the PQL for all the depth intervals, < 5 ppm for As and < .5 ppm for Cd (Figure II-3). Cu was slightly elevated in the upper levels, but were still quite low in absolute concentrations, about 8 ppm above 10 cm vs. about 6-7.5 below. Pb was only above the PQL in one interval (10-20 cm) and then only reached 10 ppm. Zn was slightly lower at the surface (about 20 ppm) and increased slightly with depth (25-30 ppm). pH was slightly lower in the upper intervals, changing from about 7.2 at the surface to about 8.5 at depth. In general, Site F-2 was very low in metals and relatively high in pH.

Site F-3: This profile shows elevated concentrations at the surface for As, Cu, Pb and Zn (Figure II-4). The values are lower than Site F-1 but higher than F-2. Arsenic is about 32 ppm in the upper 5 cm and then drops to < 10 ppm below that interval. Cd is more variable ranging from 1-2 ppm in the upper 20 cm, with the highest value, 4.5 ppm, at 30-40 cm. Below 40 cm Cd values drop to 1 ppm. Cu concentrations is about 60 ppm in the upper 5 cm and drops to about 18 ppm below, with slight decreases from 5-20 cm and 30-50 cm. Lead progressively decreases from a high at the surface of 24 ppm to < 8 ppm at the 40-50 cm interval. The Zn trend is similar to Cu with high values at the surface of 100 ppm and decreasing to about 50 ppm in the lower intervals. The upper intervals also have lower pH about 7.0 at the surface and 8.5 at depth.

Site F-4: The profile at Site F-4 shows deeper penetration of metals, arsenic and acid than the previous sites (Figure II-5). Arsenic is elevated in the upper 20 cm to about 25-28 ppm vs. < 10 ppm below 20 cm depth. Cd is mostly at or below the PQL of 1 ppm, except in the uppermost 5 cm where it is 1.4 ppm. Copper progressively decreases from a high of 58 ppm at the surface to a lower of about 18 ppm below 20 cm. Pb has a similar trend with the highest value of 37 ppm at the surface and about 14-20 ppm below that interval. Zn decreases progressively from a high of about 92 in the upper 5 cm to a low of 38 ppm at the bottom of the profile. pH is the reverse of these trends changing from about 6.5 ppm at the surface to about 9.0ppm at the lowest interval.

Site F-5: Concentrations of As, Cd and Cu are highest in the upper 5 cm of the profile at Site F-5 (Figure II-6). Arsenic values of about 40 ppm at the surface decrease abruptly to 10 ppm from 5-10 cm and < 10 ppm below 10 cm. Cd has values of 1.8 ppm in the upper 5 cm and decreases to about 1 ppm or < 1 ppm below 5 cm depth. Cu is elevated at the surface to about 60 ppm and drops to about 20 ppm below 5 cm. Pb and Zn have more variable concentrations. Pb varies from about 20-26 ppm over the entire profile, while Zn ranges from about 90 to 70 ppm. Both have slightly higher concentrations in the upper 5 cm of the profile. pH increases progressively from a low of about 6.0 at the surface to 8.0 at depth.

Site F-6: Elemental trends and concentrations at Site F-6 are very similar to those seen at Site F-1. Arsenic is highest in the upper 5 cm, 62 ppm, and decreases stepwise through 5-20 cm to < 10 ppm (figure II-7). Cd has the highest value at the surface, 1.8 ppm, and decreases to near or below the detection limit of 1 ppm below 10 cm. The highest concentration of Cu is in the upper 5 cm, 120 ppm, and it decreases abruptly below 5 cm to about 20 ppm. Pb has a similar trend decreasing from a high of 50 ppm to about 24 ppm below 5 cm. Zn decreases abruptly from 140 ppm at the surface to 80 ppm between 5-30 cm and then steps down again to 50 ppm at 30 cm. pH increases from a low of about 6.0 in the upper 10 cm to about 7.0 below that interval, with a continued increase to about 7.8 at the lowest interval.

DISCUSSION

Profiles at five of the six sites sampled have the highest elemental concentrations in the upper 5-10 cm. This trend is most obvious for As and Cu, but other elements show this increase as well. All the profiles also have lower pHs in the upper intervals. This distribution can be best explained by addition of contaminants (metals, arsenic, and sulfur oxide compounds from air-fall into the soils. By comparing the upper, elevated concentrations to reference values in the lower levels, we can determine the pollution index. For each element the relatively constant concentrations found at depth were used to establish a reference concentration before air-fall input and subsequent downward leaching. For elements that were below the PQL, the PQL was used as a reference value. Site F-2 was excluded from the analysis because of the overall very low values, likely due to dilution of the coarse grain size material at this site - cobbles and pebbles.

Arsenic was below detection of 10 ppm in the lower levels of the profiles for all the profiles, establishing a reference value of 10 ppm. This is a high value because values could be well below 10 ppm. Averaging the surface interval that showed distinct elevation above the reference values (generally 0 to 5 or 10 cm) gives a mean of 43.6 ppm ± 16.2 ppm (± one standard deviation). Using these values to calculate the contamination index (mean surface value/reference value), As is elevated about 4.4 +/- 1.6 times above the reference (pre-smelting values). In other words, there is about 4 1/2 times as much arsenic in the surface soils as would be expected if air-fall did not occur. Similar contamination indices can be determined for other elements (Table 1).

TABLE 1 Contamination indices calculated for the surface soil (upper 5 cm) at all six sites

Element	Mean Reference Values	Mean Surface Value	Contamination Index	Standard Deviation
As	10	43.6	4.36	1.62
Cu	17.8	87.6	4.92	2.22
Pb	15.7	42.3	2.68	0.95
Zn	42.5	117	2.75	0.57
pH	8.04	6.22	0.77	0.07

This analysis shows that the surface soils are elevated in some metals and arsenic from 2-5 times above the deeper reference values. Soil pH is decreased by nearly 2 pH units compared to the reference soils below.

CONCLUSION

The vertical trends in metals and pH indicate that contaminants were added to the upland soils from air-fall. Contaminants are still mostly concentrated in the upper 5-10 cm of the soils. Some elements show more mobility at certain sites, showing that some metals and acid have moved to depths of from 20-50 cm. These profiles indicate that contaminants are concentrated from about 3-5 times over reference values found deeper in the soil column.

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CHAPTER II-FIGURES

CHEMICAL CONCENTRATIONS IN VERTICAL PROFILES OF UPLAND SOILS AT GRANT–KOHRS RANCH NATIONAL HISTORIC SITE

GEOCHEMISTRY AND FLUVIAL GEOMORPHOLOGY

REPORT

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Figure II-1

Figure II-1 Location of upland soil profile sampling sites.

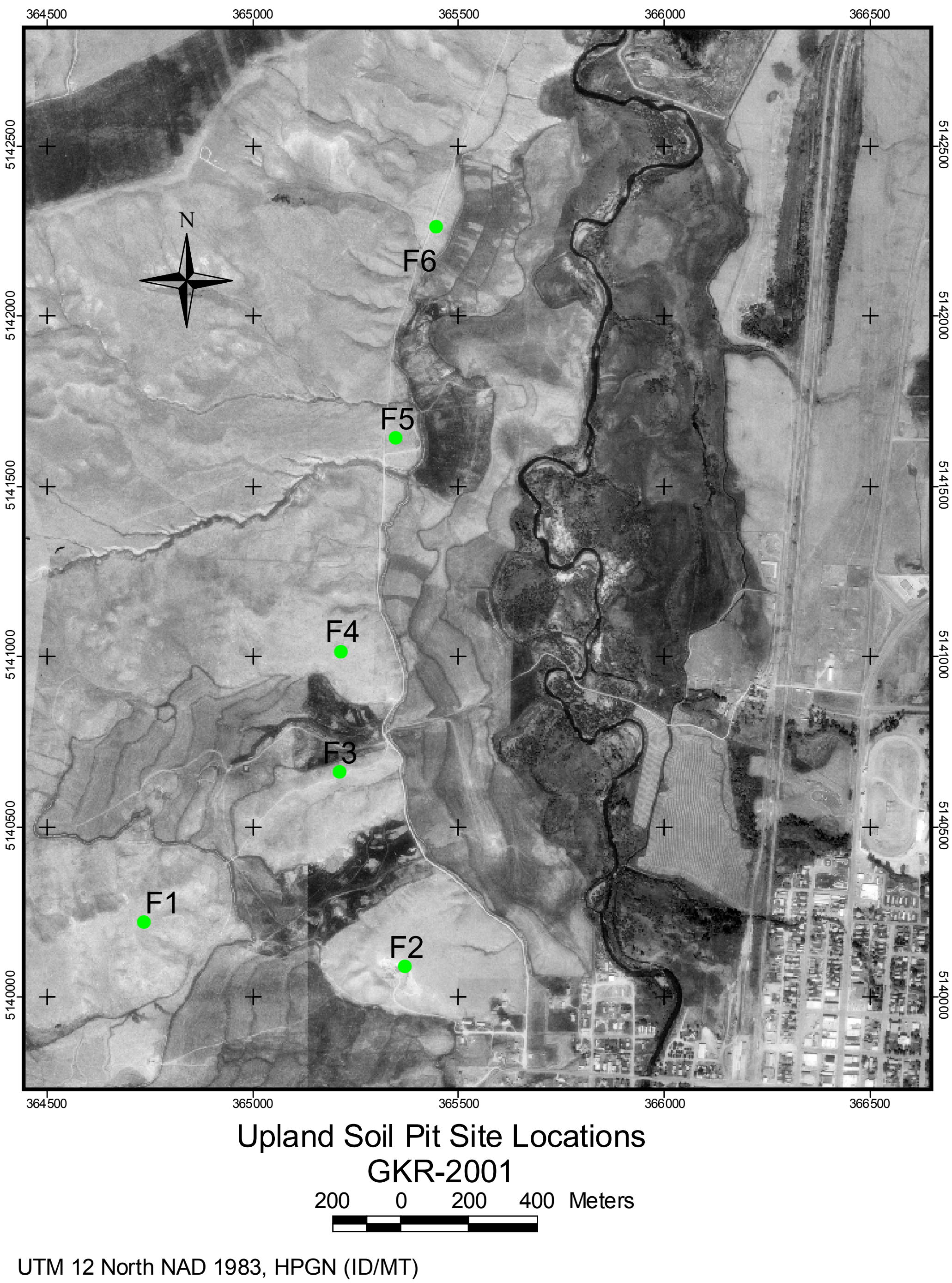


Figure II-2

Figure II-2 Site F1 vertical trends. Circles represent the values for the interval samples. Values below the detection limit (PQL) are plotted as half the detection limit for convenience. Detection limits used are: As = 10 ppm; Cd = 1 ppm; Cu = 6 ppm; Pb = 8 ppm; Zn = 16 ppm.Any values plotted below these values should be considered below detection.

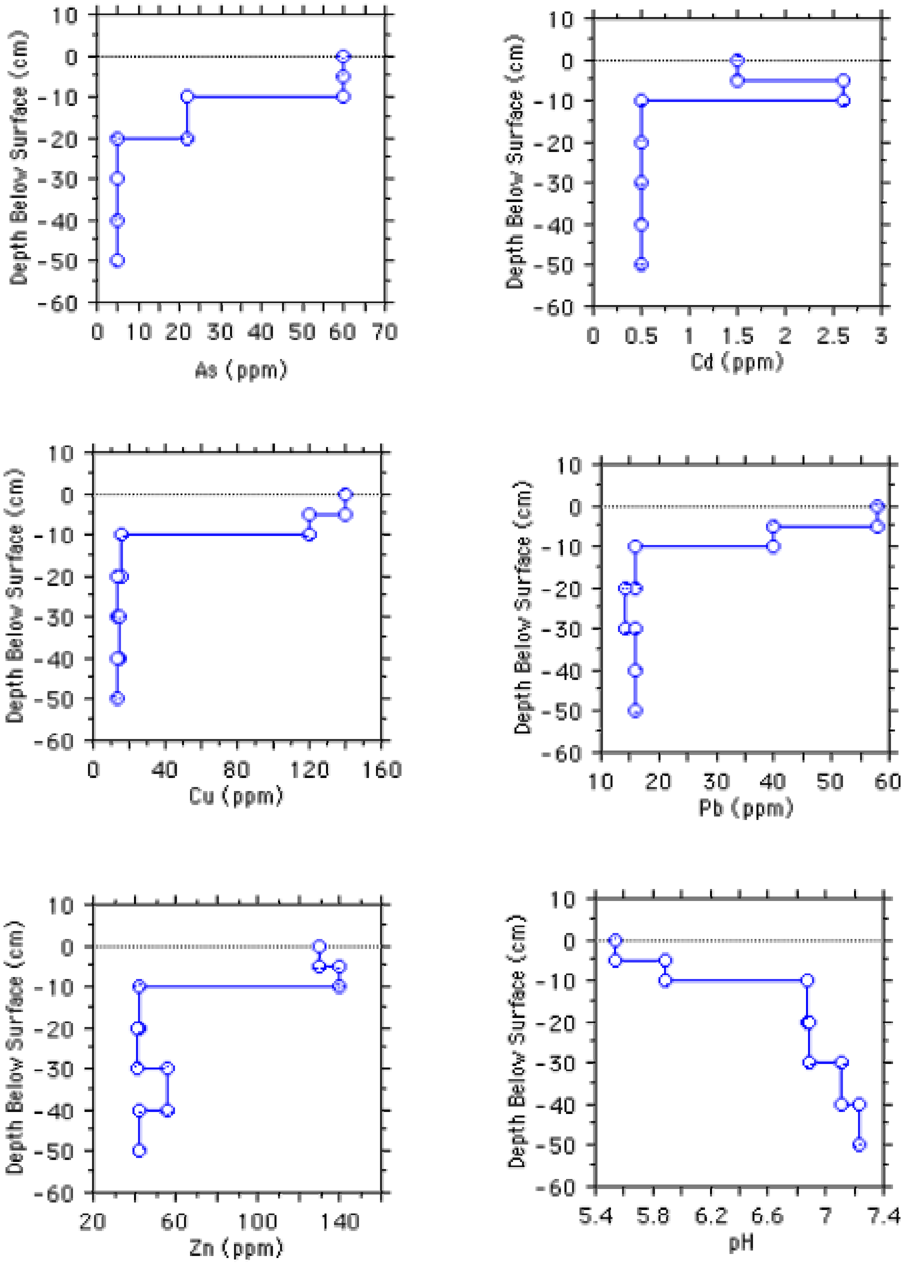


Figure II-3

Figure II-3 Site F2 vertical trends. (See Figure II-2 for explanation)

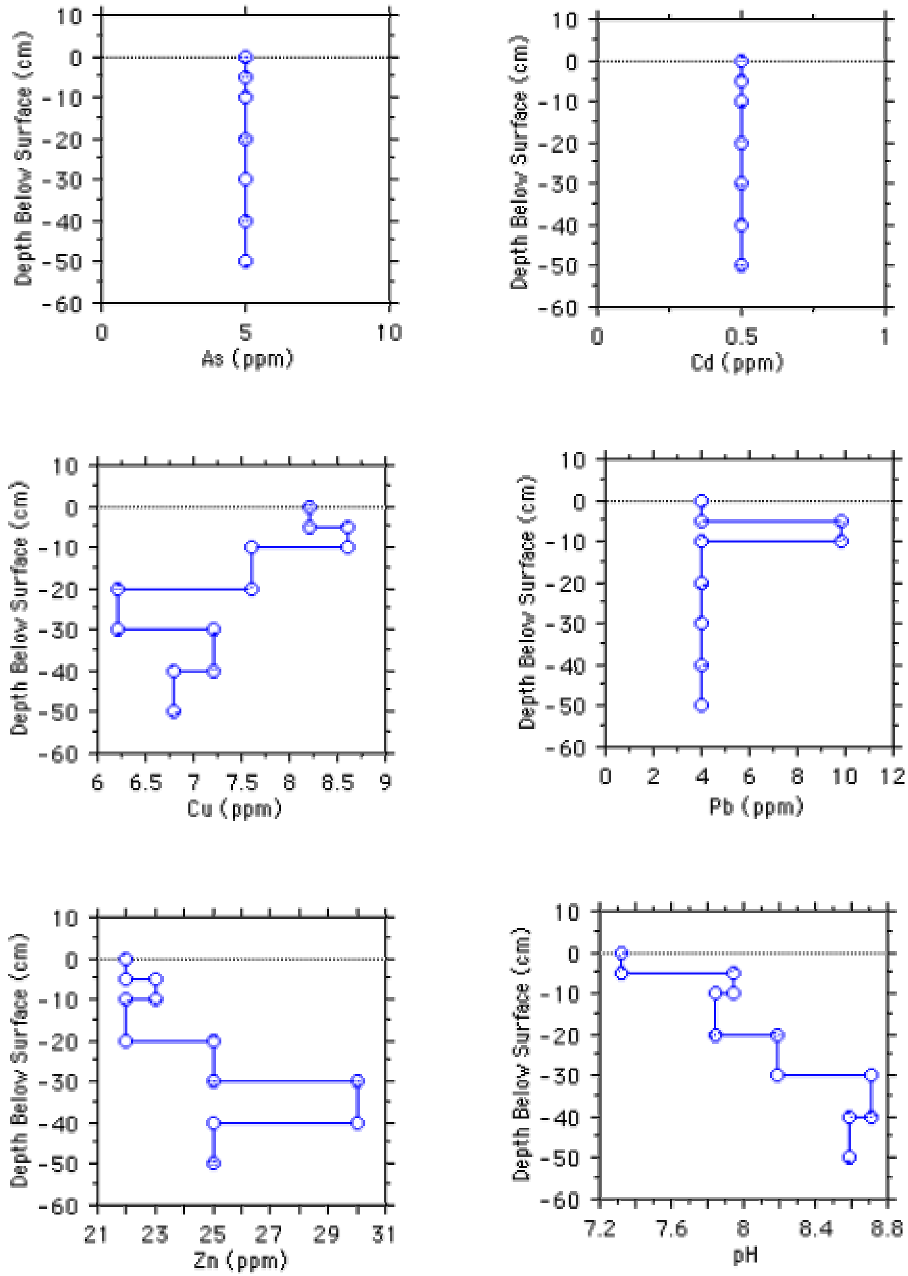


Figure II-4

Figure II-4 Site F3 vertical trends. (See Figure II-2 for explanation)

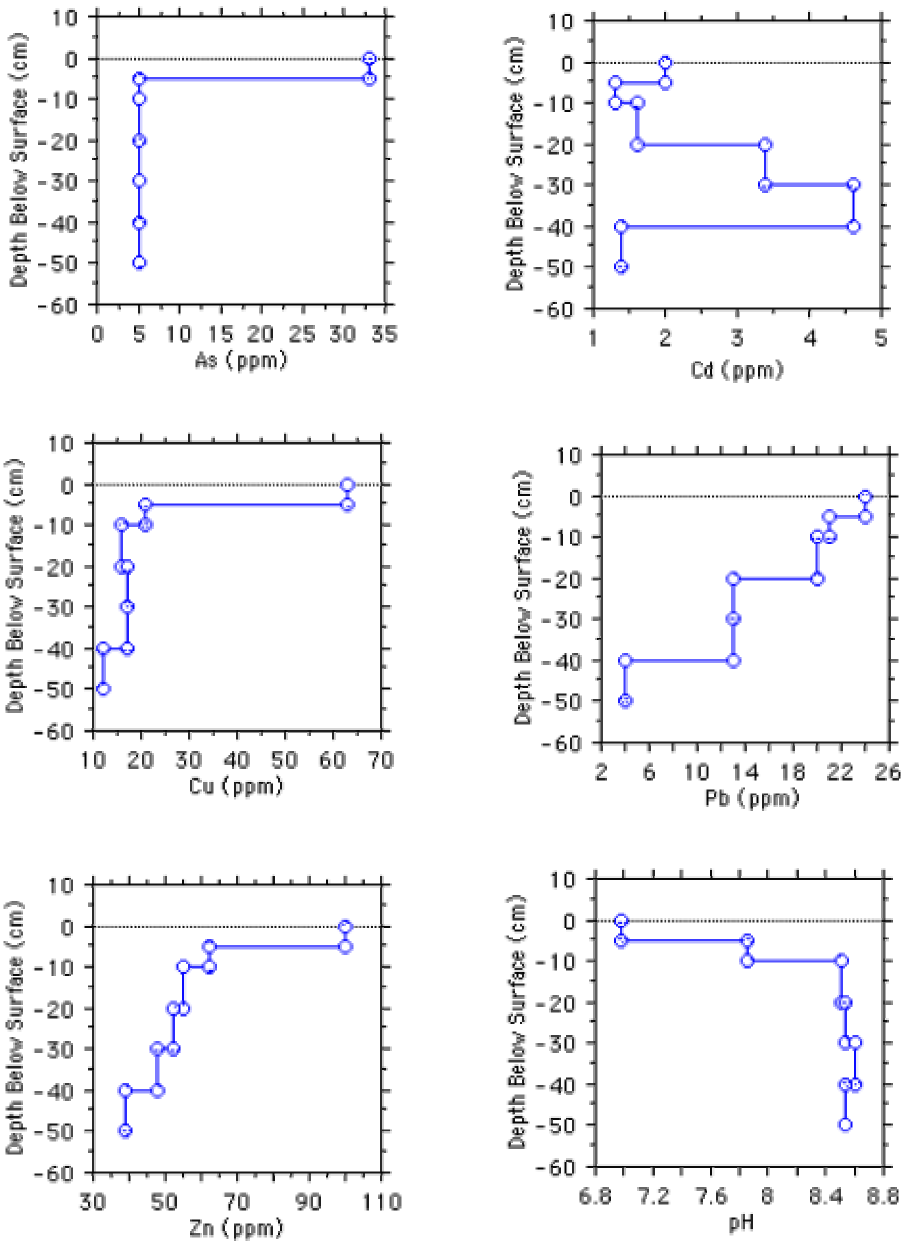


Figure II-5

Figure II-5 Site F4 vertical trends. (See Figure II-2 for explanation)

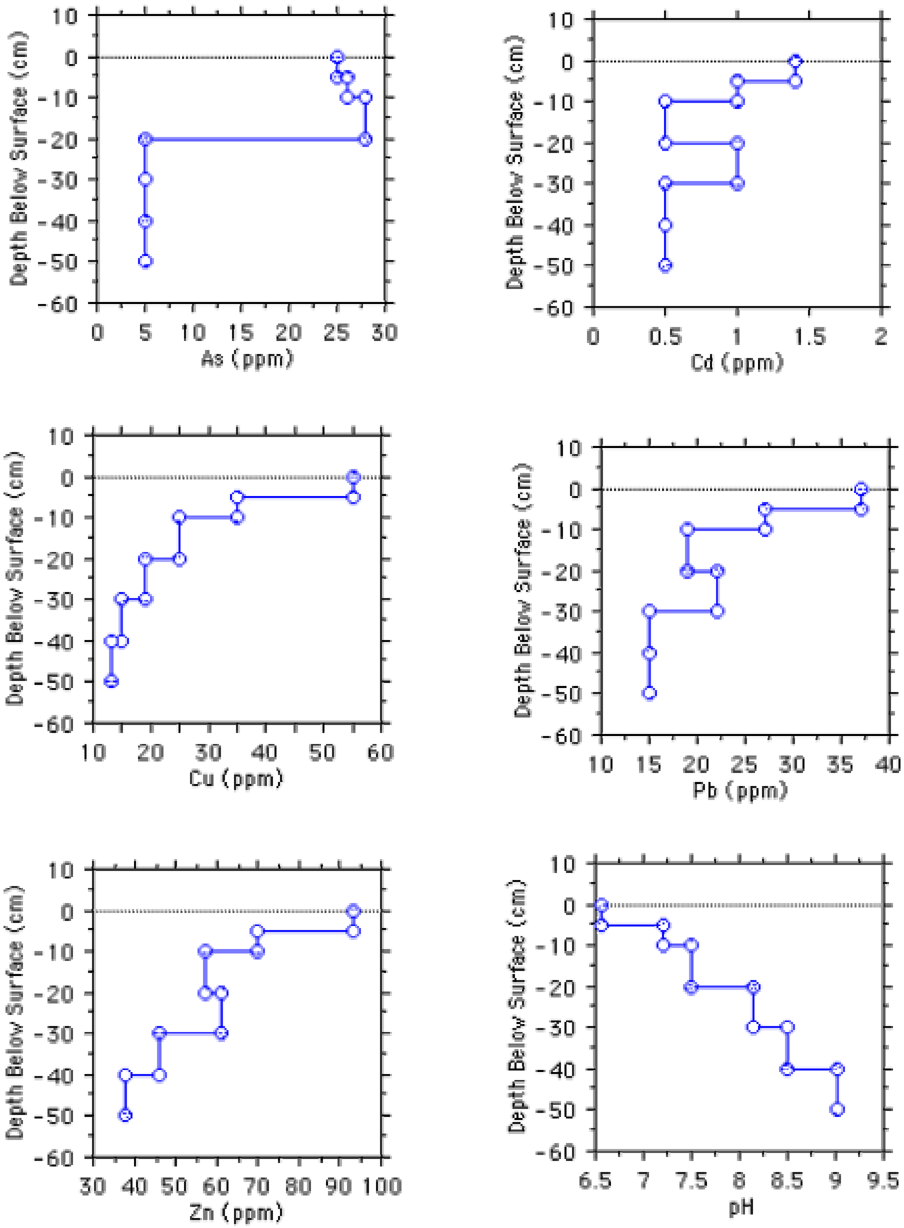


Figure II-6

Figure II-6 Site F5 vertical trends. (See Figure II-2 for explanation)

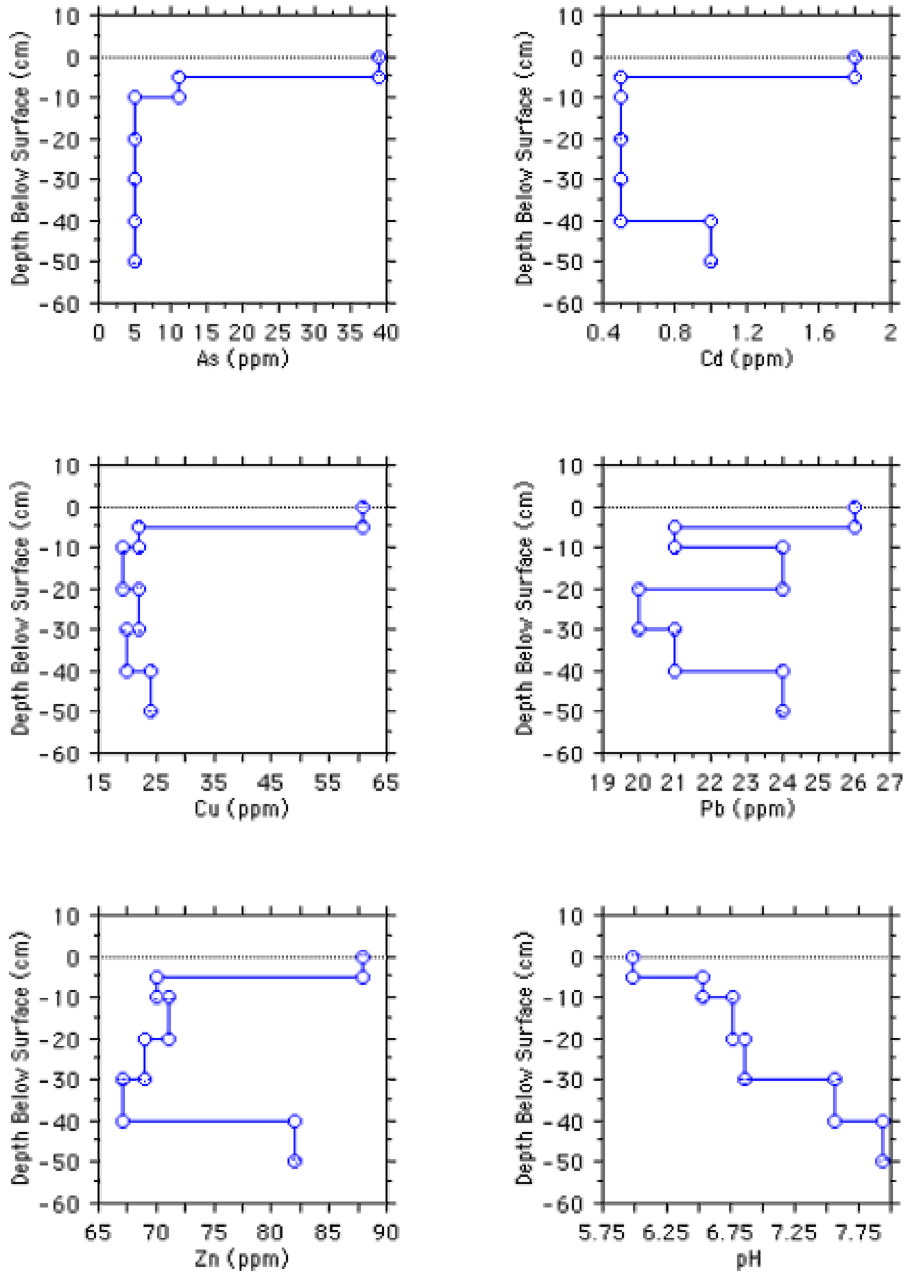
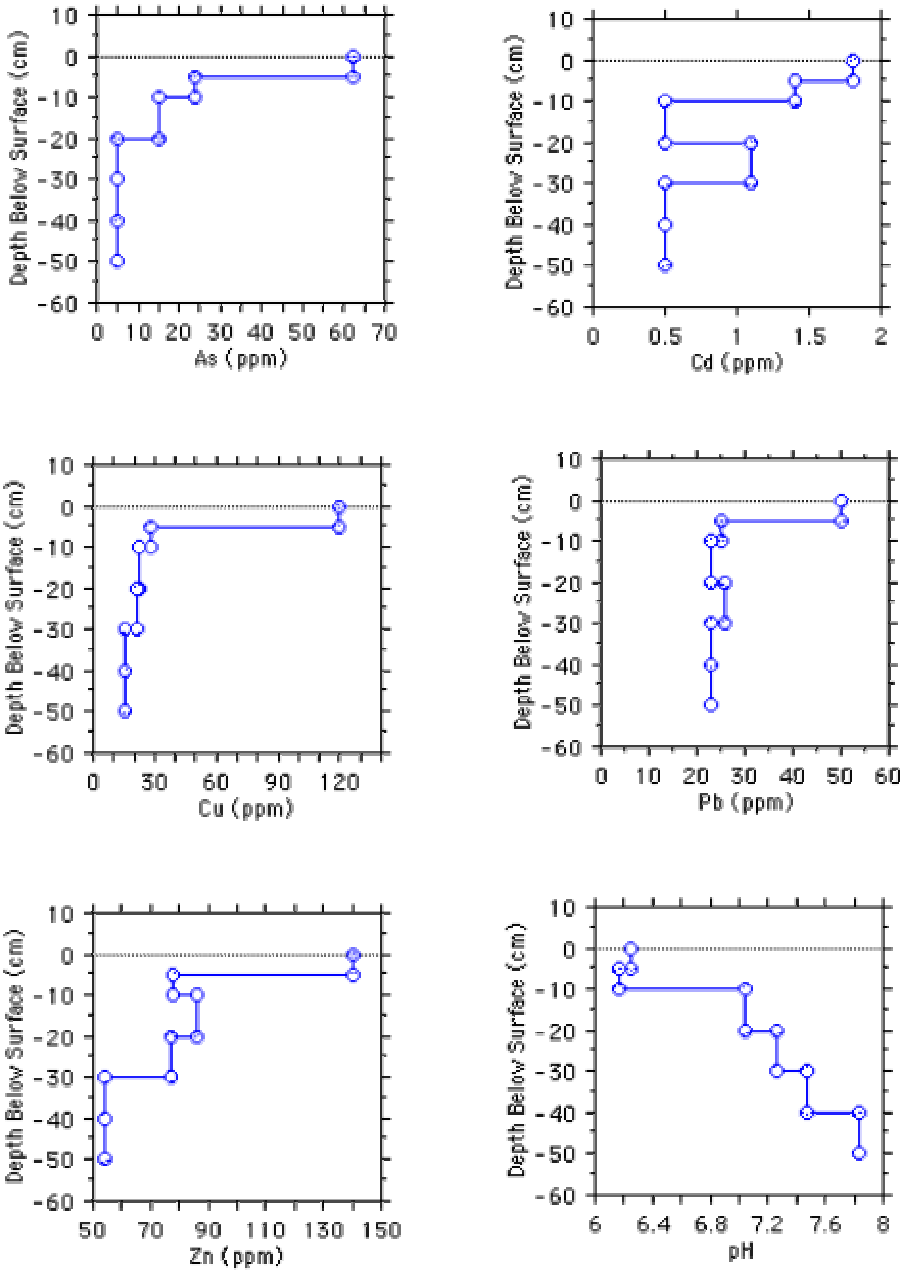


Figure II-7

Figure II-7 Site F6 vertical trends. (See Figure II-2 for explanation)



CHAPTER III

CHEMICAL CONCENTRATIONS IN SURFACE SOILS OF THE BLM TRACTS ALONG THE CLARK FORK RIVER

GEOCHEMISTRY AND FLUVIAL GEOMORPHOLOGY

REPORT

A DRAFT REPORT TO THE GRANT-KOHRS RANCH NATIONAL HISTORIC SITE

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INTRODUCTION

Soil microbial respiration studies were conducted at tracts owned by the BLM (tracts 3, 7, 8, 9, 12, 13, and 15) along the Clark Fork River. Associated with those biological studies, the concentration of metals was determined at each of the sites. The results of those analyses are reported in this data report and compared to values determined at Grant-Kohrs Ranch.

METHODS

The soil sampling methods used at the Gran-Kohrs Ranch megaplot sites were also implemented at the BLM soil sampling sites (see Chapter I and SAP) so that results from the microbial study could be compared to metals concentrations. Sites were chosen based on previous qualitative data collected by the BLM (P. Bierbach, personal communication). The geochemistry of the soils was determined by compositing soil samples from the upper 6 inches of the soil profile. Four surface soil samples were collected using a soil hand auger (see SOP SS-1). The four sub-samples were homogenized to prepare a single composite sample. The samples were stored and transported to the laboratory for sample preparation and analysis. Samples were transported to the laboratory following chain-of-custody procedures as per the QAP and SOPs QA-7, QA-8, QA-9, and QA-10. Upon laboratory receipt, samples were split into three portions as per SOP SS-13. For total metals analysis, each subsample was dried and ground to ensure sample homogeneity (see SOP SS-3). They were transferred to labeled and sealed plastic containers (e.g., snap-cap vials) and stored in a secure area until digestion. Samples were digested according to a modified EPA Method 3050B (see SOP EPA 3050B) for the extraction of total metals. Digests were analyzed for total metals by ICAP-ES according to modified EPA Method 200.7 (see SOP EPA 200.7). Samples were also analyzed for pH. Elements of concern include arsenic, cadmium, copper, lead, and zinc.

RESULTS

The detailed data for the sites at each tract is presented in Appendix I-A. Maps of the distribution of the constituents measured are presented in Figures III-8 to III-80. An overview of the average values found and relationships to 2001 data collected at Grant-Kohrs Ranch are presented here.

ARSENIC

Mean concentrations of arsenic were highest at Tract 9 (T9, Table III-1) and lowest at Tract 8 (T8, Table III-1). The mean concentrations at all the tracts were considerably lower than concentrations found at Grant-Kohrs Ranch (GRKO, Table III-1). The mean arsenic concentration at GRKO was 361 ppm, where the highest concentration found at any of the tracts was 79 ppm (Table III-1). The range in arsenic concentration at all the sites in all the tracts was from a low of 22 ppm to a high of 95 ppm, whereas at GRKO values ranged from 32 ppm to 880 ppm.

TABLE III-1 Descriptive Statistics for Arsenic for Each Tract and for the Grant-Kohrs Ranch Megaplot Sites.

	Mean	Std. Dev.	Number	Minimum	Maximum
As (ppm), T3	52	16	12	29	84
As (ppm), T7	54	18	2	42	67
As (ppm), T8	31	8	3	22	37
As (ppm), T9	79	11	5	68	95
As (ppm), T12	42	16	9	22	68
As (ppm), T13	34	12	4	24	50
As (ppm), T15	38	18	2	25	50
As (ppm), GRKO	361	224	30	32	880

CADMIUM

Mean concentrations of cadmium were also highest at Tract 9 (T9, Table III-2) and lowest at Tract 15 (T15, Table III-2). The mean concentrations at all the tracts were considerably lower than concentrations found at Grant-Kohrs Ranch (GRKO, Table III-2). The mean cadmium concentration at Grant-Kohrs Ranch was 7.2 ppm, where the highest concentration found at any of the tracts was 4.9 ppm (Table III-2). The range in cadmium concentration at all the sites in all the tracts was from a low of 1.2 ppm to a high of 4.9 ppm, whereas at GRKO values ranged from 3.2 ppm to 16 ppm.

TABLE III-2 Descriptive Statistics for Cadmium for Each Tract and for the Grant-Kohrs Ranch Megaplot Sites.

	Mean	Std. Dev.	Number	Minimum	Maximum
Cd (ppm), T3	2.7	.9	12	1.6	4.2
Cd (ppm), T7	3.4	.9	2	2.7	4.0
Cd (ppm), T8	2.3	.5	3	1.9	2.8
Cd (ppm), T9	4.3	.6	5	3.4	4.9
Cd (ppm), T12	2.6	1.2	9	1.2	4.8
Cd (ppm), T13	2.2	.6	4	1.5	2.9
Cd (ppm), T15	2.1	1.2	2	1.3	3.0
Cd (ppm), GRKO	7.2	3.1	30	3.2	16

COPPER

Mean concentrations of copper were also highest at Tract 9 (T9, Table III-3) and lowest at Tract 8 (T8, Table III-3). The mean concentrations at all the tracts were considerably lower than concentrations found at Grant-Kohrs Ranch (GRKO, Table III-3). The mean copper concentration at Grant-Kohrs Ranch was 2579 ppm, where the highest concentration found at any of the tracts was 1100 ppm (Table III-3). The range in copper concentration at all the sites in all the tracts was from a low of 170 ppm to a high of 1100 ppm, whereas at GRKO values ranged from 600 ppm to 7100 ppm.

TABLE III-3 Descriptive Statistics for Copper for Each Tract and for the Grant-Kohrs Ranch Megaplot Sites.

	Mean	Std. Dev.	Number	Minimum	Maximum
Cu (ppm), T3	439	237	12	210	1100
Cu (ppm), T7	475	106	2	400	550
Cu (ppm), T8	240	70	3	170	310
Cu (ppm), T9	782	156	5	550	960
Cu (ppm), T12	340	125	9	190	580
Cu (ppm), T13	285	78	4	200	380
Cu (ppm), T15	340	198	2	200	480
Cu (ppm), GRKO	2579	1632	30	600	7100

LEAD

Mean lead concentrations were also highest at Tract 9 (T9, Table III-4) and lowest at Tract 13 (T13, Table III-4). The mean concentrations at all the tracts were considerably lower than concentrations found at Grant-Kohrs Ranch (GRKO, Table III-4). The mean lead concentration at GRKO was 381 ppm, where the highest concentration found at any of the tracts was 230 ppm (Table III-4). The range in lead concentration at all the sites in all the tracts was from a low of 42 ppm to a high of 230 ppm, whereas at GRKO values ranged from 110 ppm to 1100 ppm.

TABLE III-4 Descriptive Statistics for Lead for Each Tract and for the Grant-Kohrs Ranch Megaplot Sites.

	Mean	Std. Dev.	Number	Minimum	Maximum
Pb (ppm), T3	89	47	12	50	230
Pb (ppm), T7	82	13	2	73	92
Pb (ppm), T8	61	23	3	42	87
Pb (ppm), T9	111	12	5	96	120
Pb (ppm), T12	65	20	9	45	110
Pb (ppm), T13	60	16	4	43	80
Pb (ppm), T15	62	28	2	42	81
Pb (ppm), GRKO	381	212	30	110	1100

ZINC

Mean zinc concentrations were also highest at Tract 9 (T9, Table III-5) and lowest at Tract 15 (T15, Table III-5). The mean concentrations at all the tracts were lower than concentrations found at Grant-Kohrs Ranch (GRKO, Table III-5) but much closer than for any of the other metals. The mean zinc concentration at GRKO was 1592 ppm. The highest concentration found at any of the tracts was 1900 ppm (Table III-5), somewhat higher than the mean at Grant-Kohrs Ranch. The range in zinc concentration at all the sites in all the tracts was from a low of 170 ppm to a high of 1900 ppm, whereas at Grant-Kohrs Ranch values ranged from 720 ppm to 2900 ppm.

TABLE III-5 Descriptive Statistics for Zinc for Each Tract and for the Grant-Kohrs Ranch Megaplot Sites.

	Mean	Std. Dev.	Number	Minimum	Maximum
Zn (ppm), T3	738	202	12	450	1100
Zn (ppm), T7	935	233	2	770	1100
Zn (ppm), T8	807	156	3	640	950
Zn (ppm), T9	1192	298	5	810	1500
Zn (ppm), T12	824	530	9	170	1900
Zn (ppm), T13	635	124	4	480	770
Zn (ppm), T15	600	240	2	430	770
Zn (ppm), GRKO	1592	563	30	720	2900

OVERVIEW COMPARISONS

As can be seen by the data presented in the above tables, metal and arsenic concentrations are generally lower in the BLM tracts than in the Grant-Kohrs Ranch Megaplots sites. This can be visualized in a series of box plots that compare all the BLM tract data with all the Grant-Kohrs Ranch Megaplot data (37 vs. 30 sites, respectively)(Figure III-1).

Although concentrations of metals and arsenic are lower in the soils of the BLM tracts than those found at Grant-Kohrs Ranch, comparisons made to the baseline values determined at Grant-Kohrs Ranch show that they are elevated (Figure III-2) above baseline. The majority of the arsenic and lead values are elevated over three times the baseline values, cadmium two times, copper 20 times, and zinc ten times.

TRACT COMPARISONS

Differences in multiples above baseline concentrations are identifiable among the different tracts (see Figures III-3 to III-7). Tract 9 has the highest values for As, Cd, Cu, Pb and Zn. For As, Cu and Pb, the next highest values are found in Tracts 3 and 7, although the differences are more subdued for Pb. For Cd and Zn Tract 7 is somewhat lower than Tract 9 and all the other tracts show a large amount of variability but generally lower values than either Tract 9 or 7.

CONCLUSIONS

The above data show that the BLM tracts have metal and arsenic concentrations elevated above the baseline values found at Grant-Kohrs Ranch. Copper is the element most elevated at all the sites and occurs at multiples of baseline much higher than the other elements. The other elements follow in the order Zn > As > Pb > Cd.

Tract 9 has the highest levels of contamination for all elements considered, followed by Tract 7. The other tracts have relatively equivalent and lower contamination levels.

CHAPTER III-FIGURES

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Figure III-1

FIGURE III-1 Box Plots of Metals and Arsenic in Soils from Grant-Kohrs Ranch Megaplot Sites and BLM Tracts. See Figure I-2 for explanation.

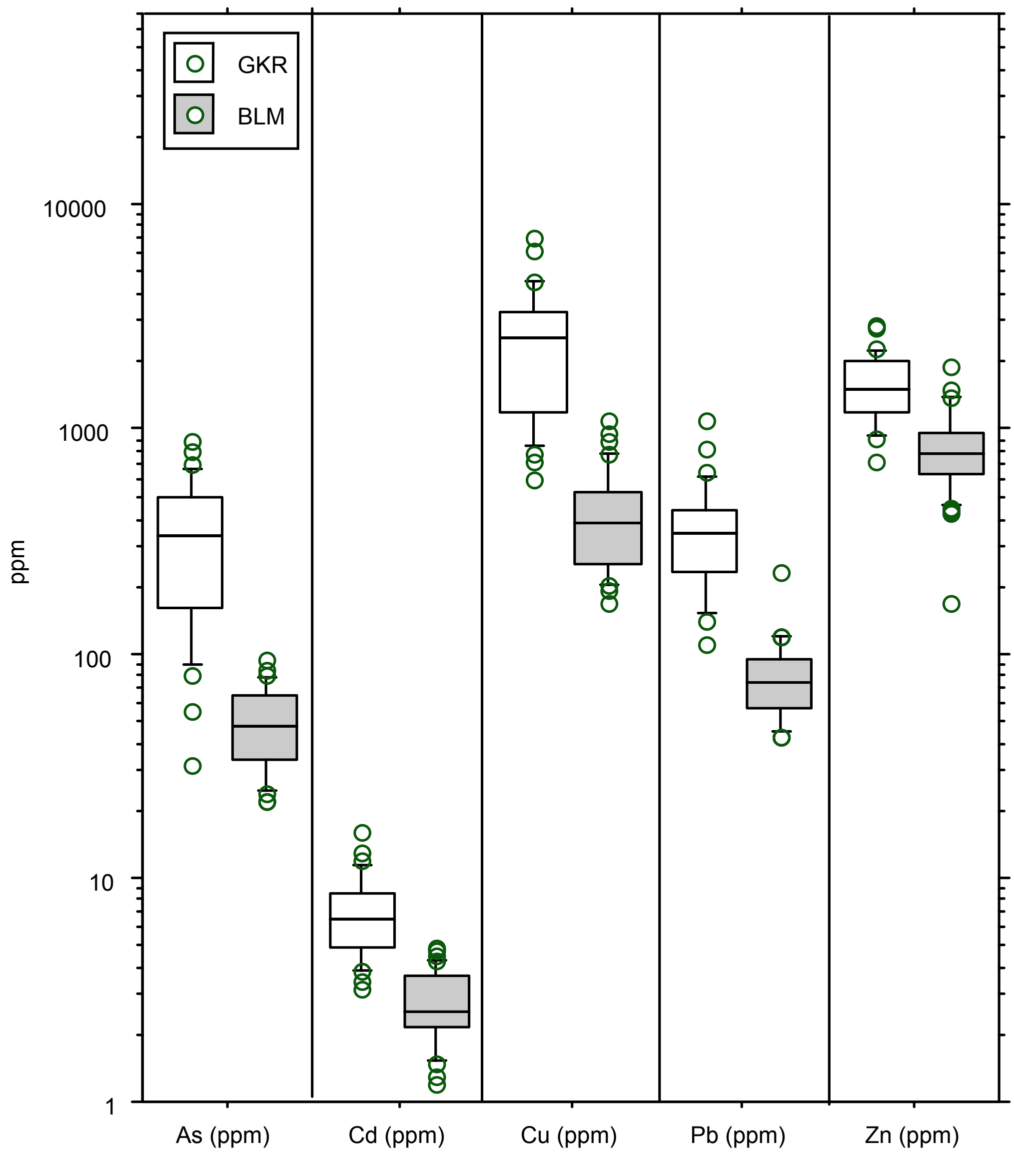


Figure III-2

FIGURE III-2 Box Plots of Multiples of Baseline Concentrations for Metals and Arsenic in Soils from all BLM Tracts. See Figure I-2 for explanation of box plots.

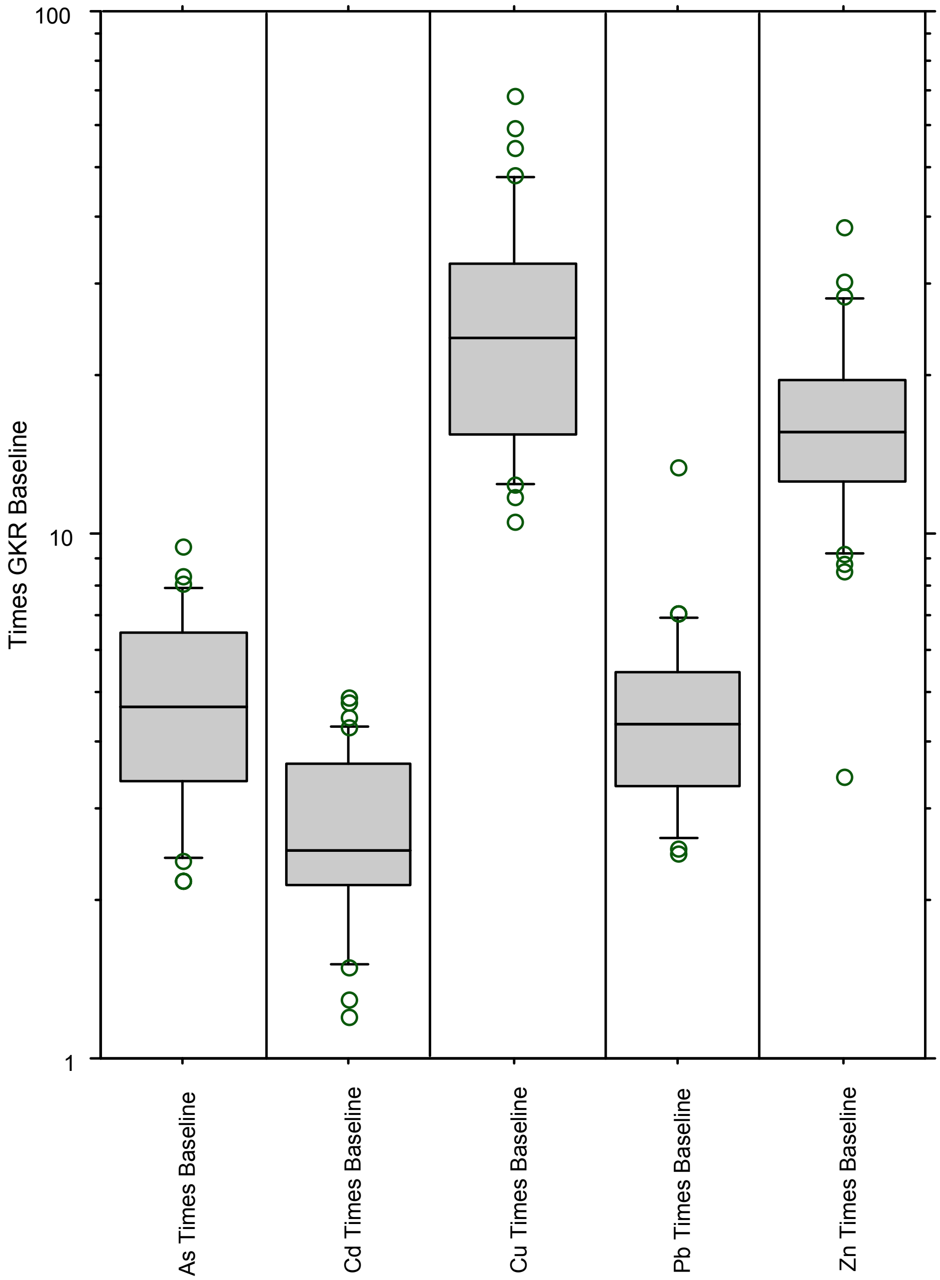


Figure III-3

FIGURE III-3 Box Plots of Arsenic Multiples of Baseline at Individual BLM Tracts. See Figure I-2 for explanation.

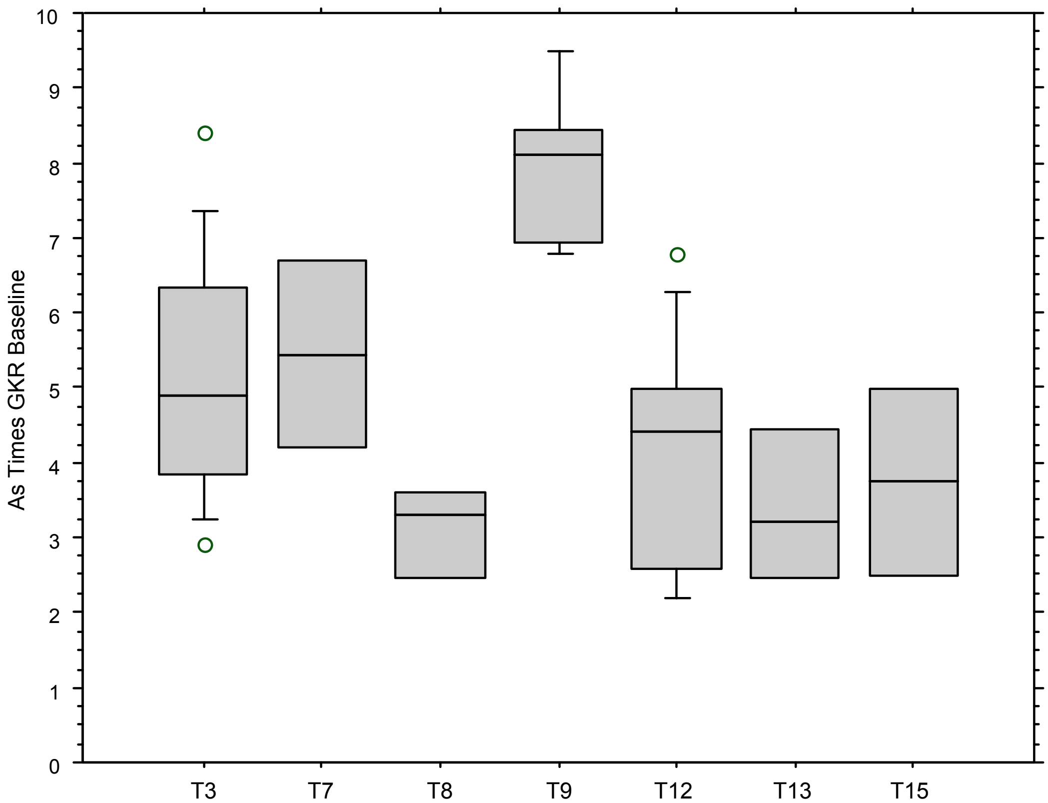


Figure III-4

FIGURE III-4 Box Plots of Cadmium Multiples of Baseline at Individual BLM Tracts. See Figure I-2 for explanation.

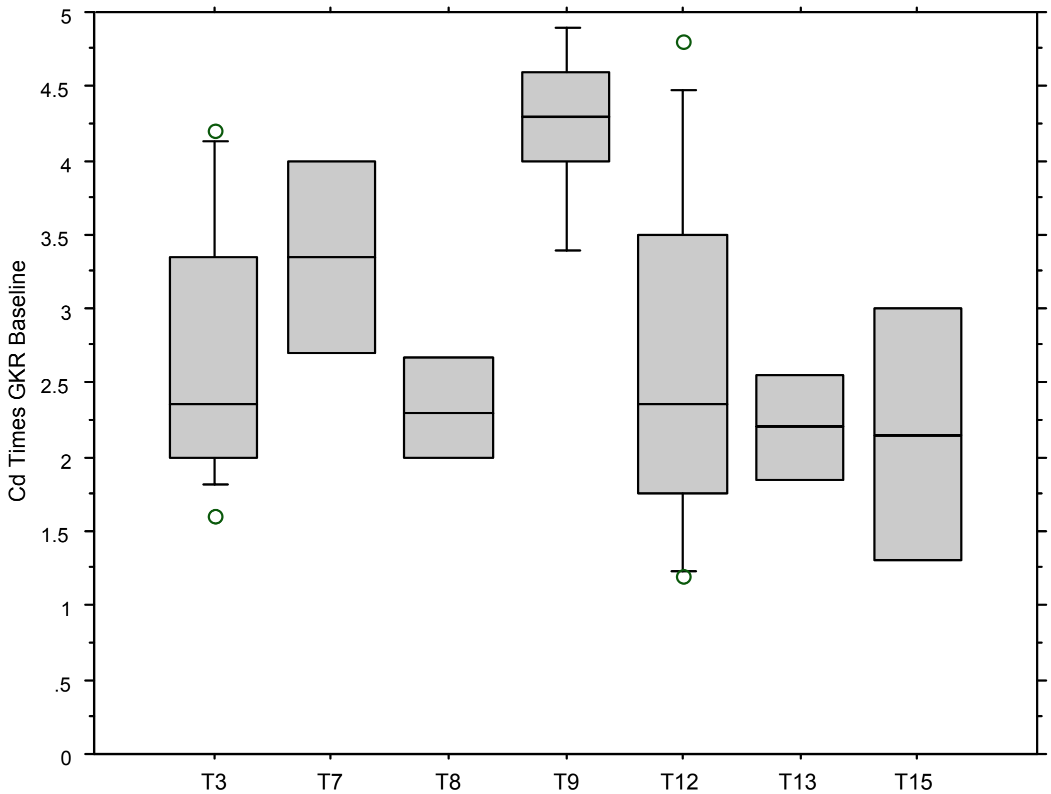


Figure III-5

FIGURE III-5 Box Plots of Copper Multiples of Baseline at Individual BLM Tracts. See Figure I-2 for explanation.

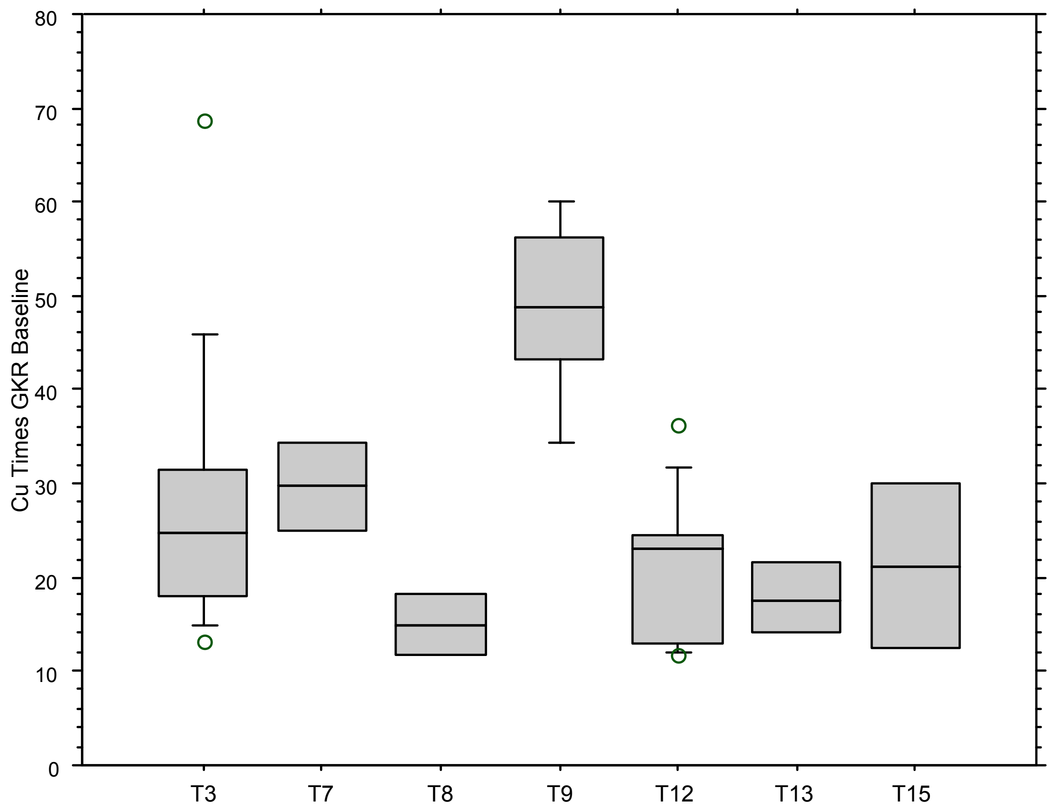


Figure III-6

FIGURE III-6 Box Plots of Lead Multiples of Baseline at Individual BLM Tracts. See Figure I-2 for explanation.

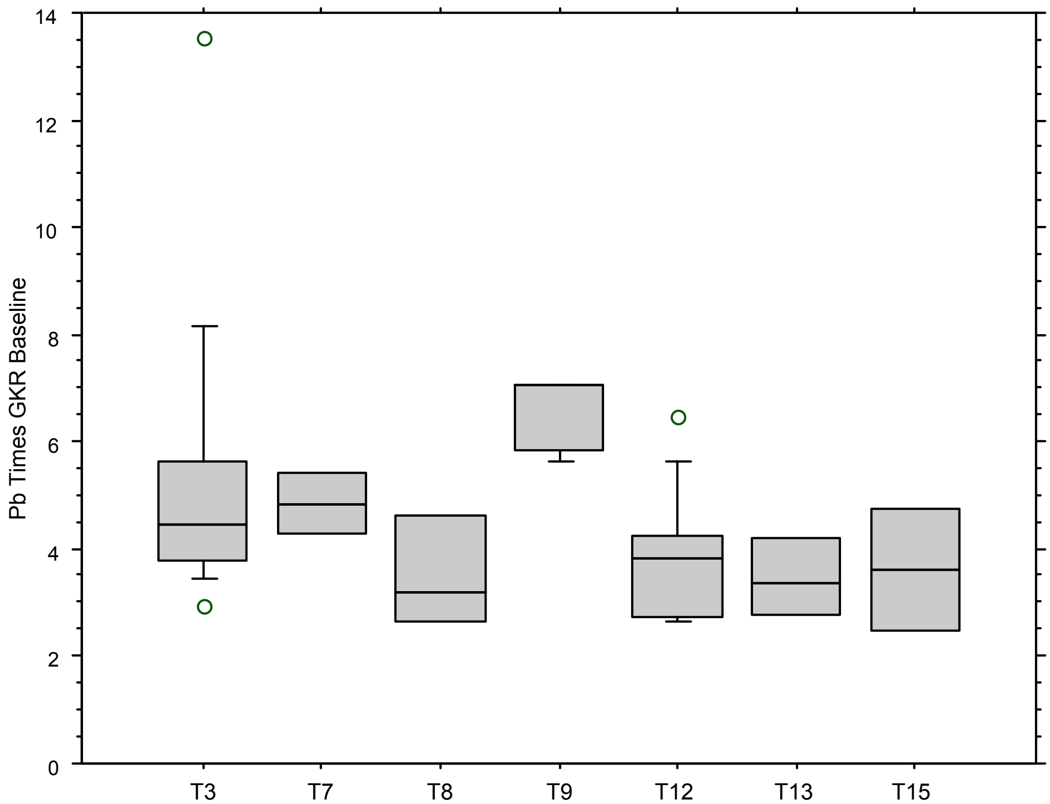
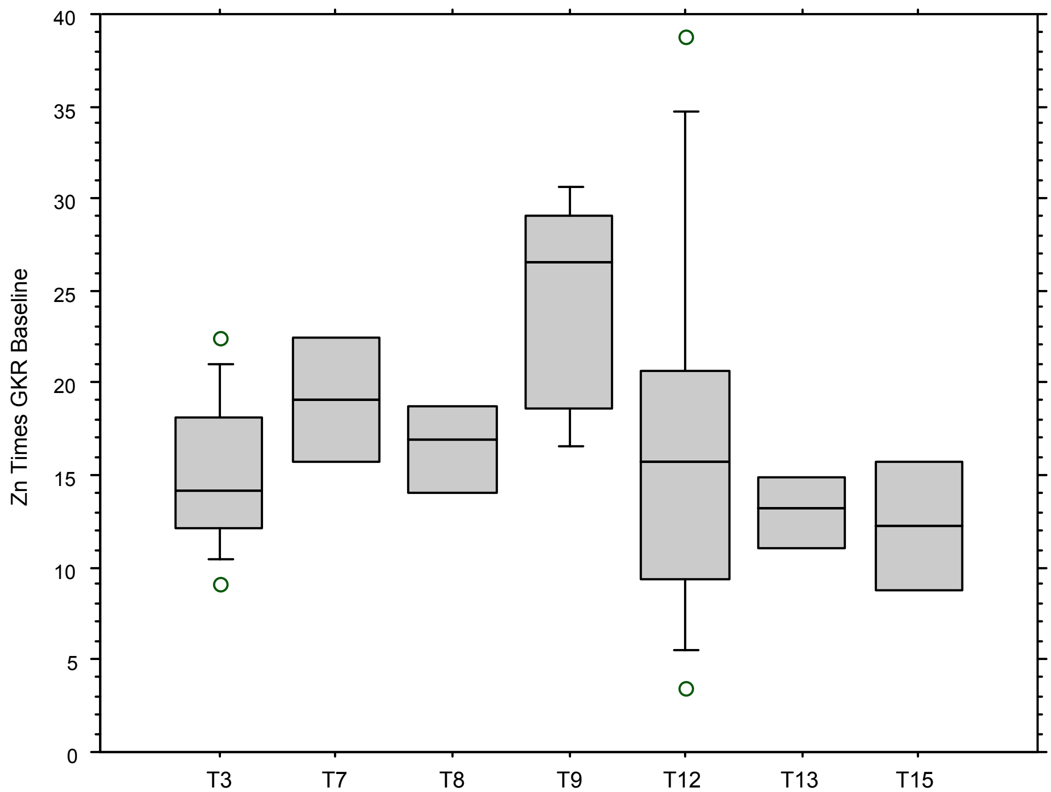


Figure III-7

FIGURE III-7 Box Plots of Zinc Multiples of Baseline at Individual BLM Tracts. See Figure I-2 for explanation.

See Figure I-2 for explanation.



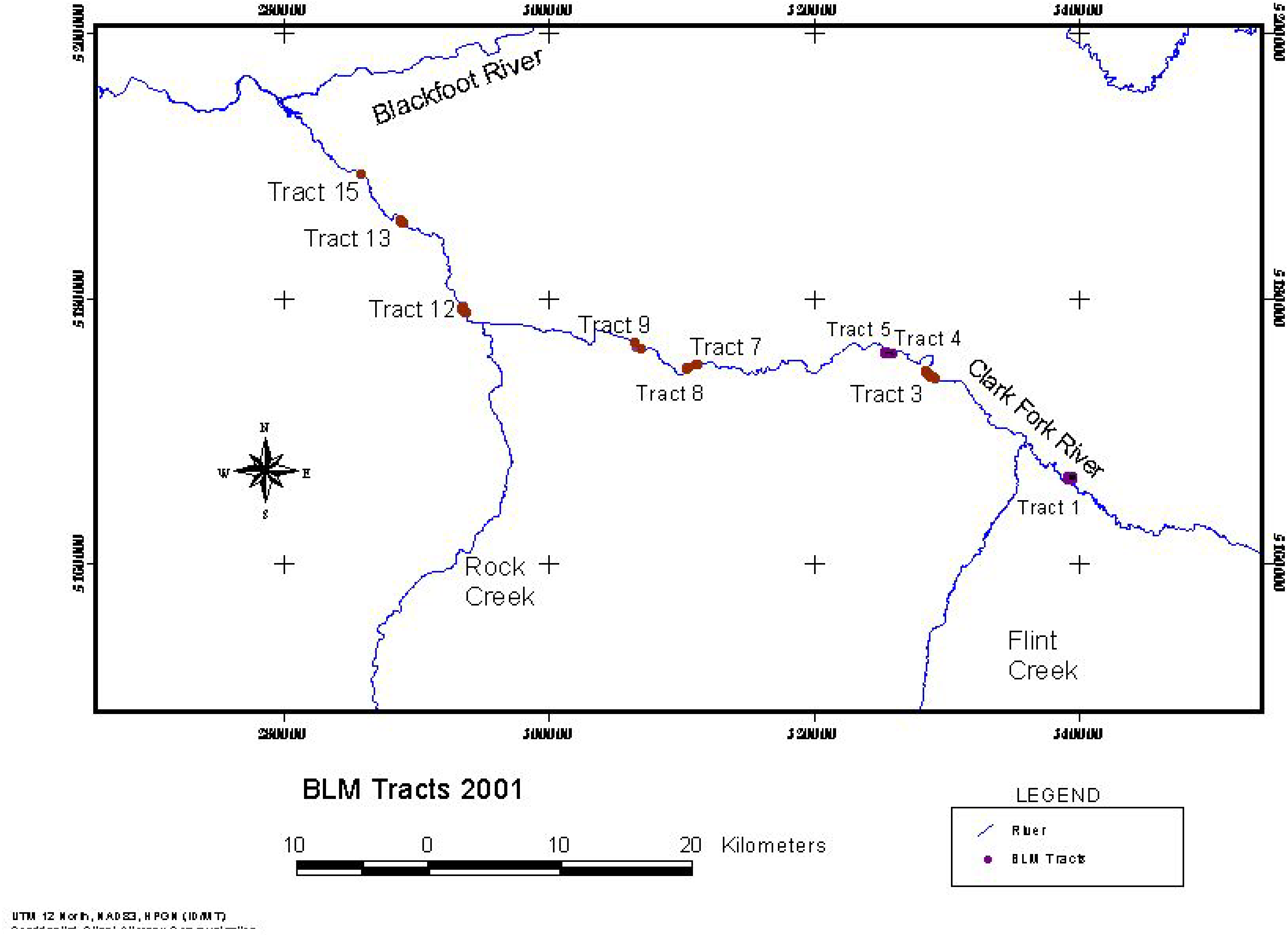
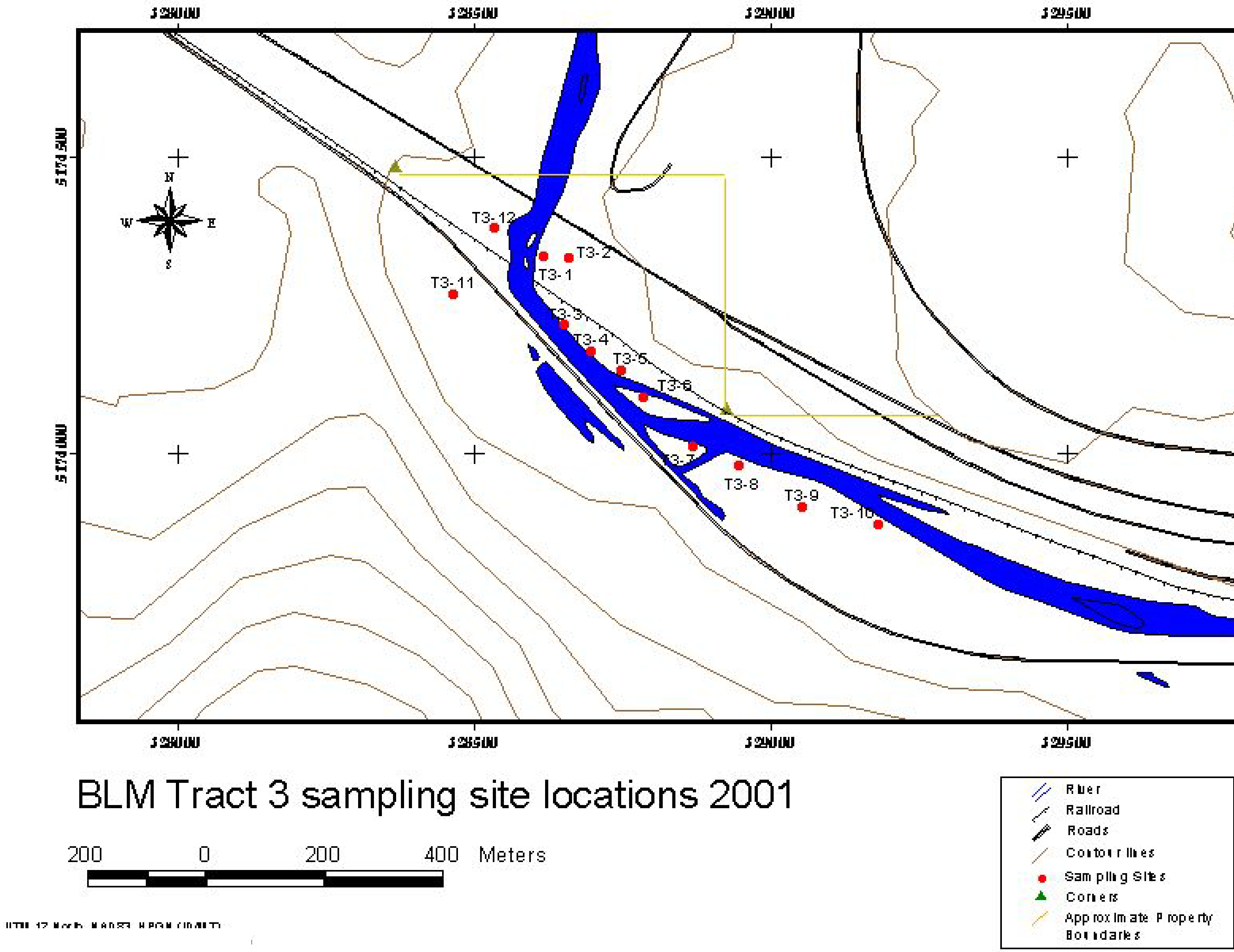

Blackfoot River
Tract 15
Tract 13
Tract 12
Tract 9
Tract 7
Tract 8
Tract 5
Tract 4
Tract 3
Clark Fork River
Tract 1
Rock Creek
Flint Creek
N
W
E
S
BLM Tracts 2001
10
0
10
20
Kilometers
LEGEND
River
BLM Tracts

Figure III-8



328000
328500
329000
329500
5174500
5174000
N
W
E
S
T3-1
T3-2
T3-3
T3-4
T3-5
T3-6
T3-7
T3-8
T3-9
T3-10
T3-11
T3-12
BLM Tract 3 sampling site locations 2001
200 0 200 400 Meters
River
Railroad
Roads
Contour lines
Sampling Sites
Corners
Approximate Property Boundaries

Figure III-9

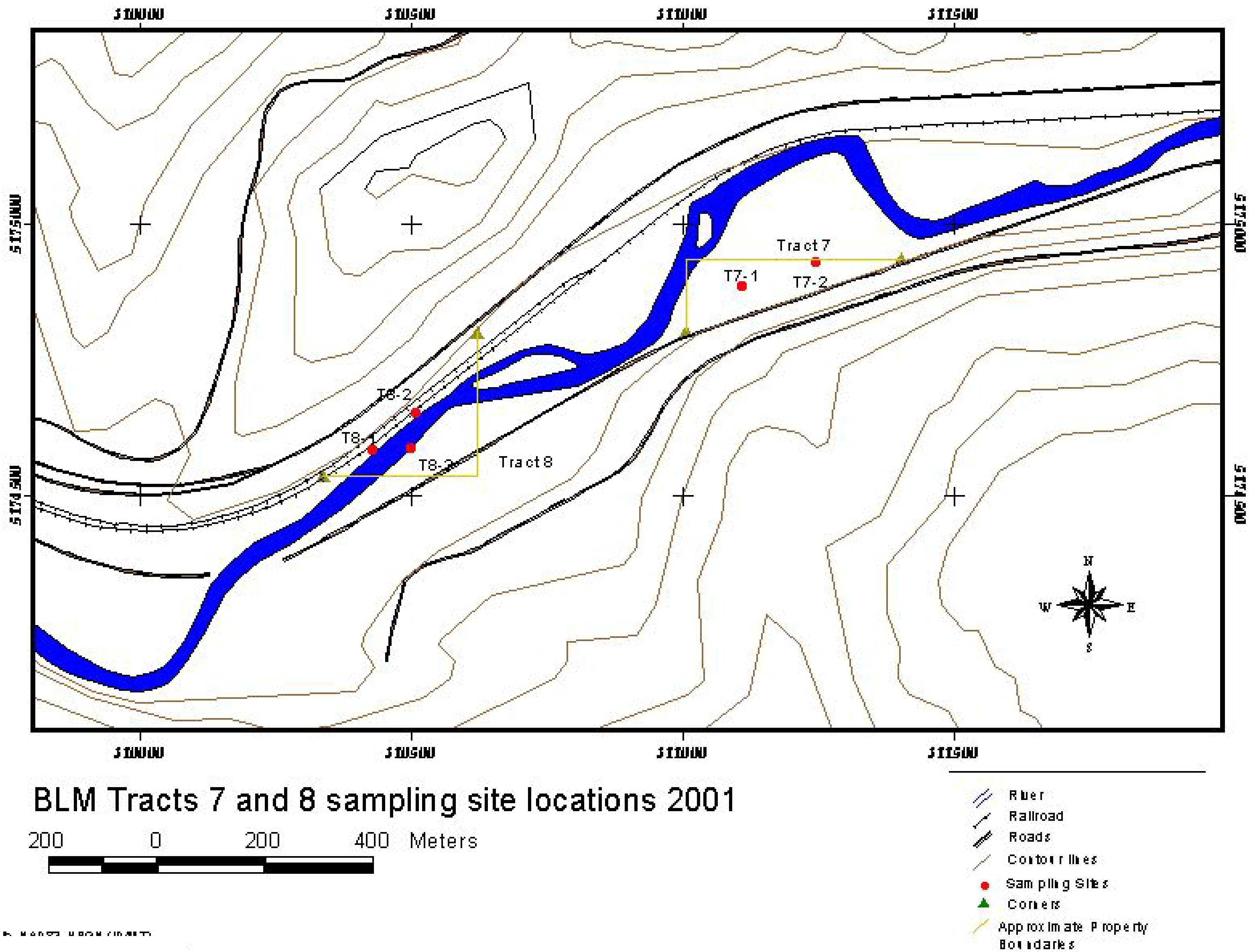


Figure III-10

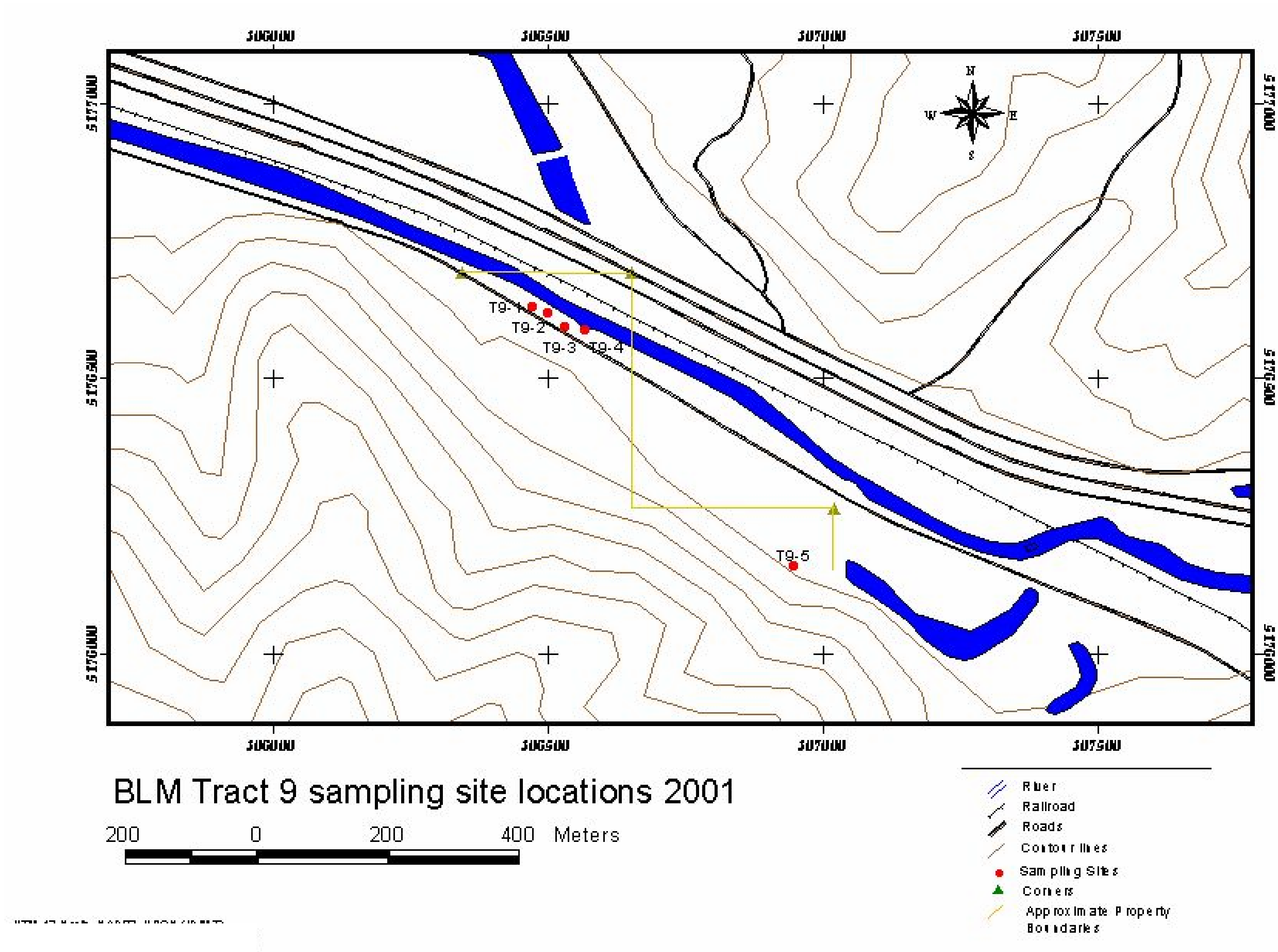


Figure III-11

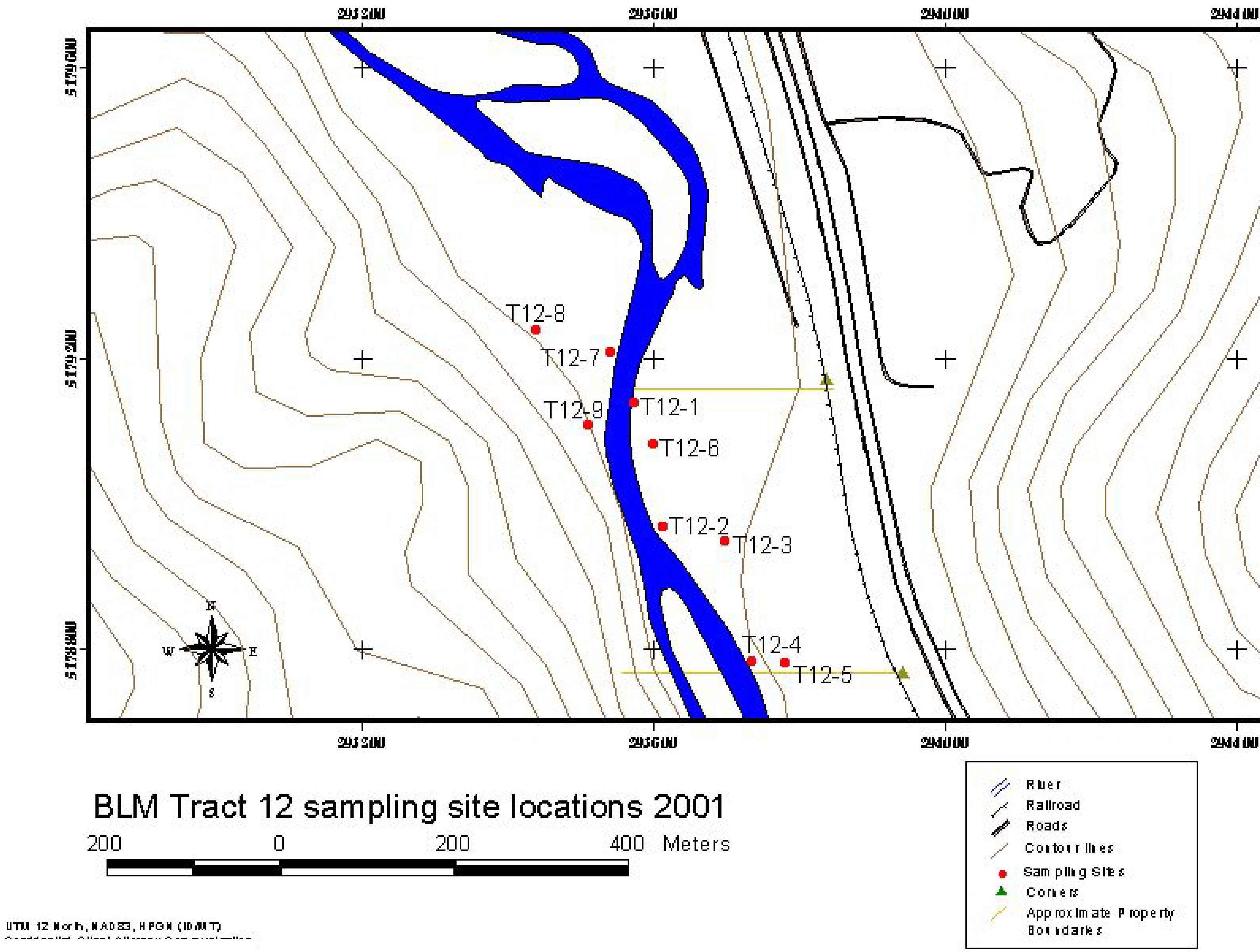


Figure III-12

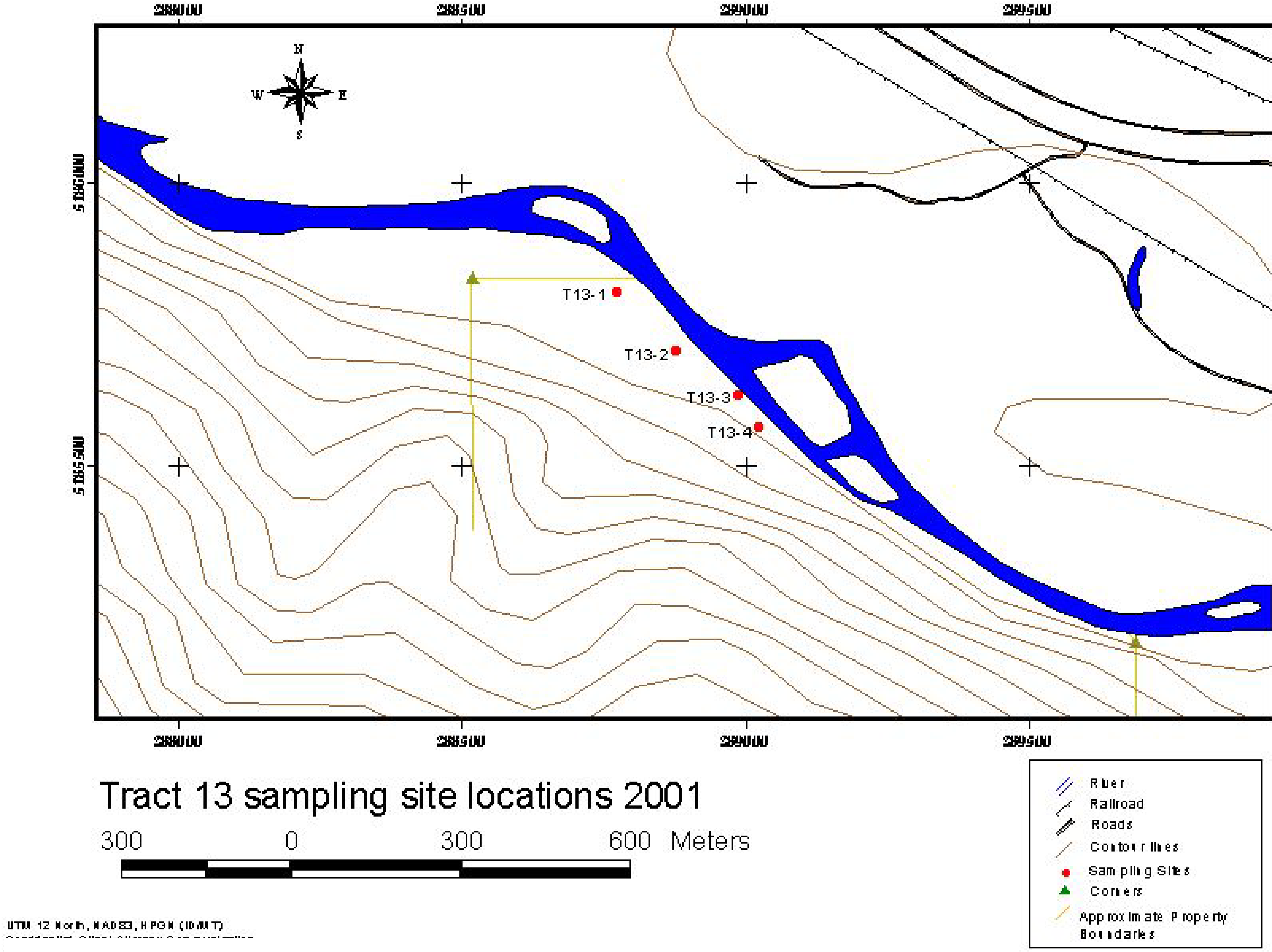
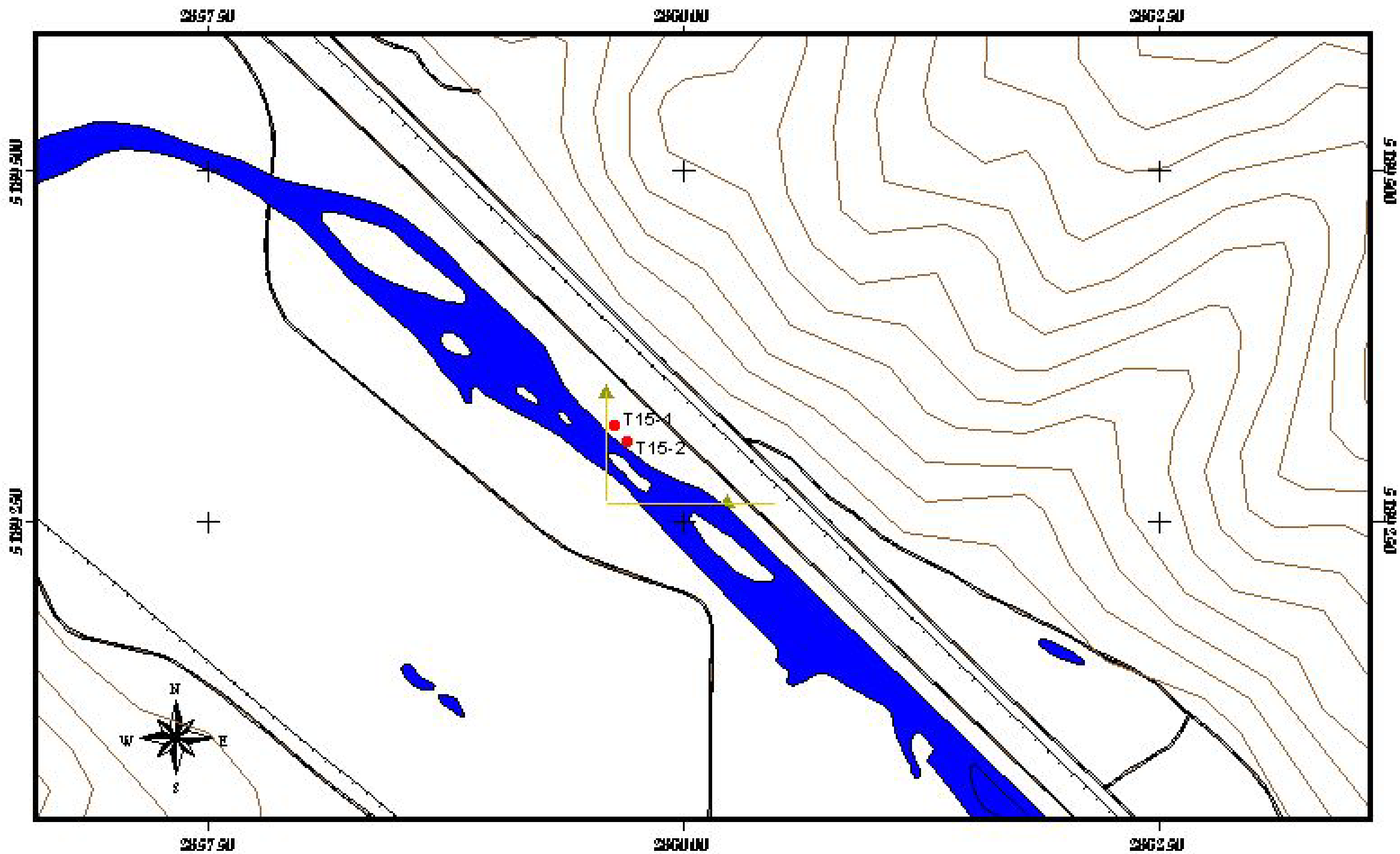


Figure III-13



BLM Tract 15 sampling site locations 2001

200 0 200 400 Meters

Figure III-14

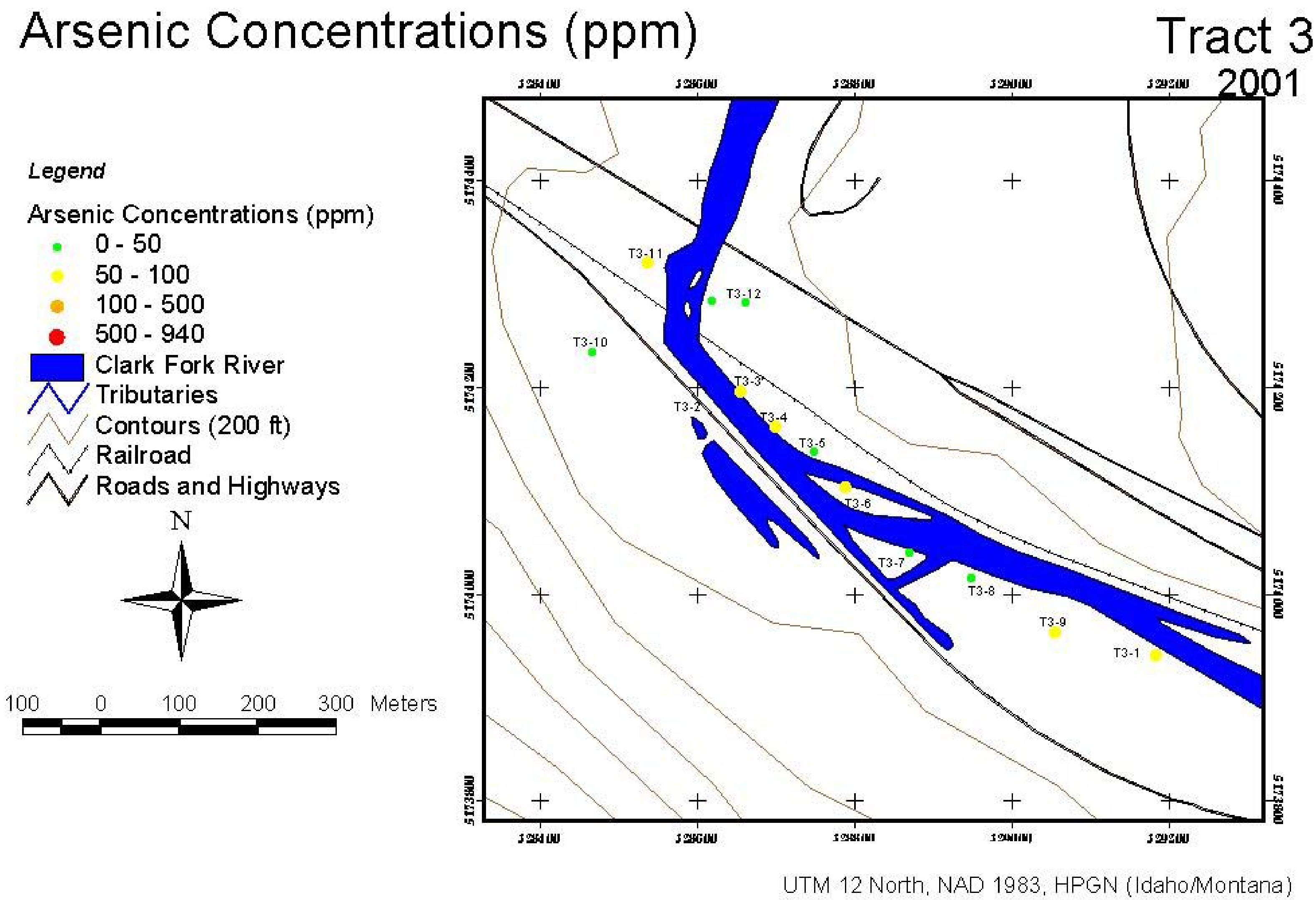


Figure III-15

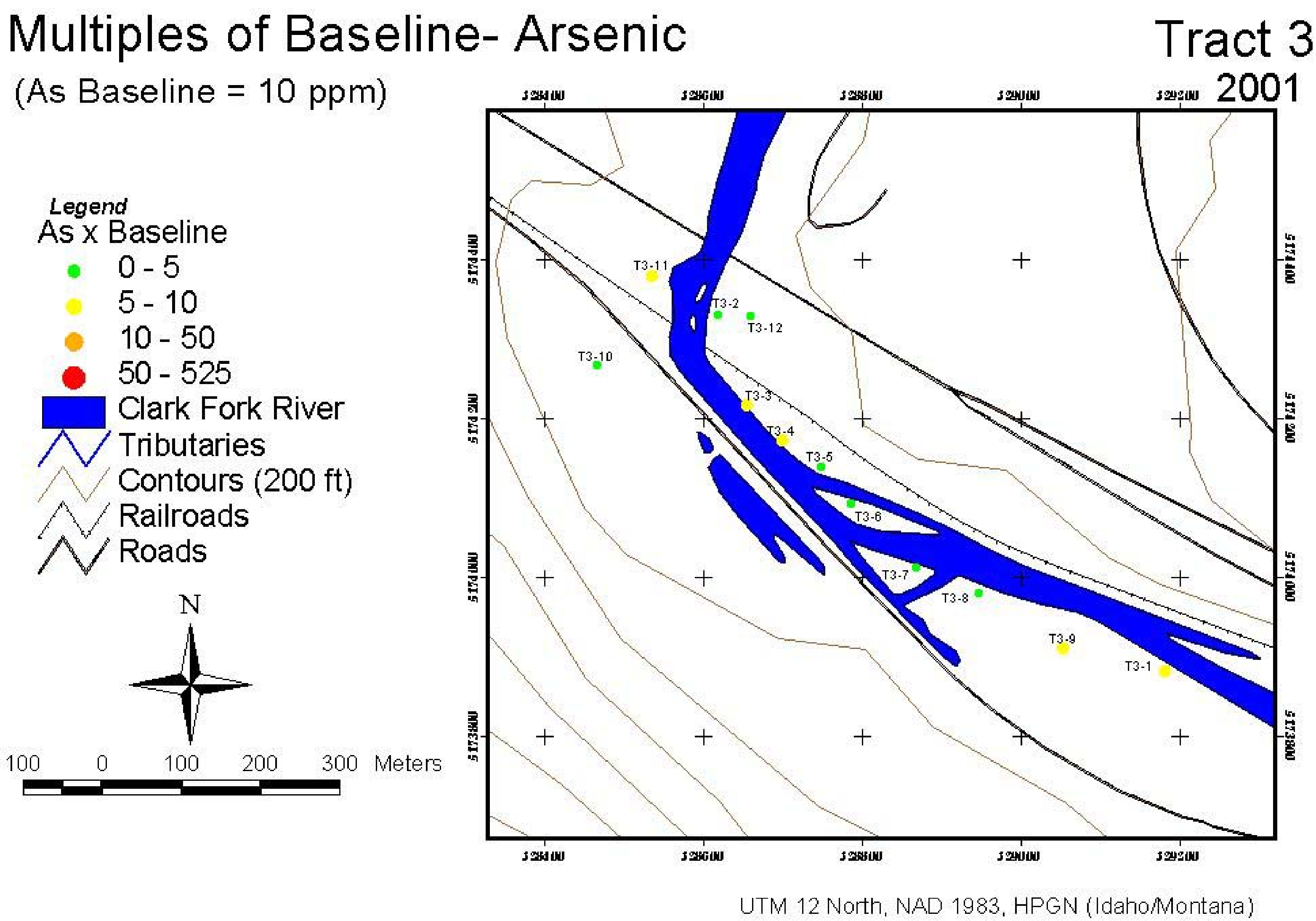
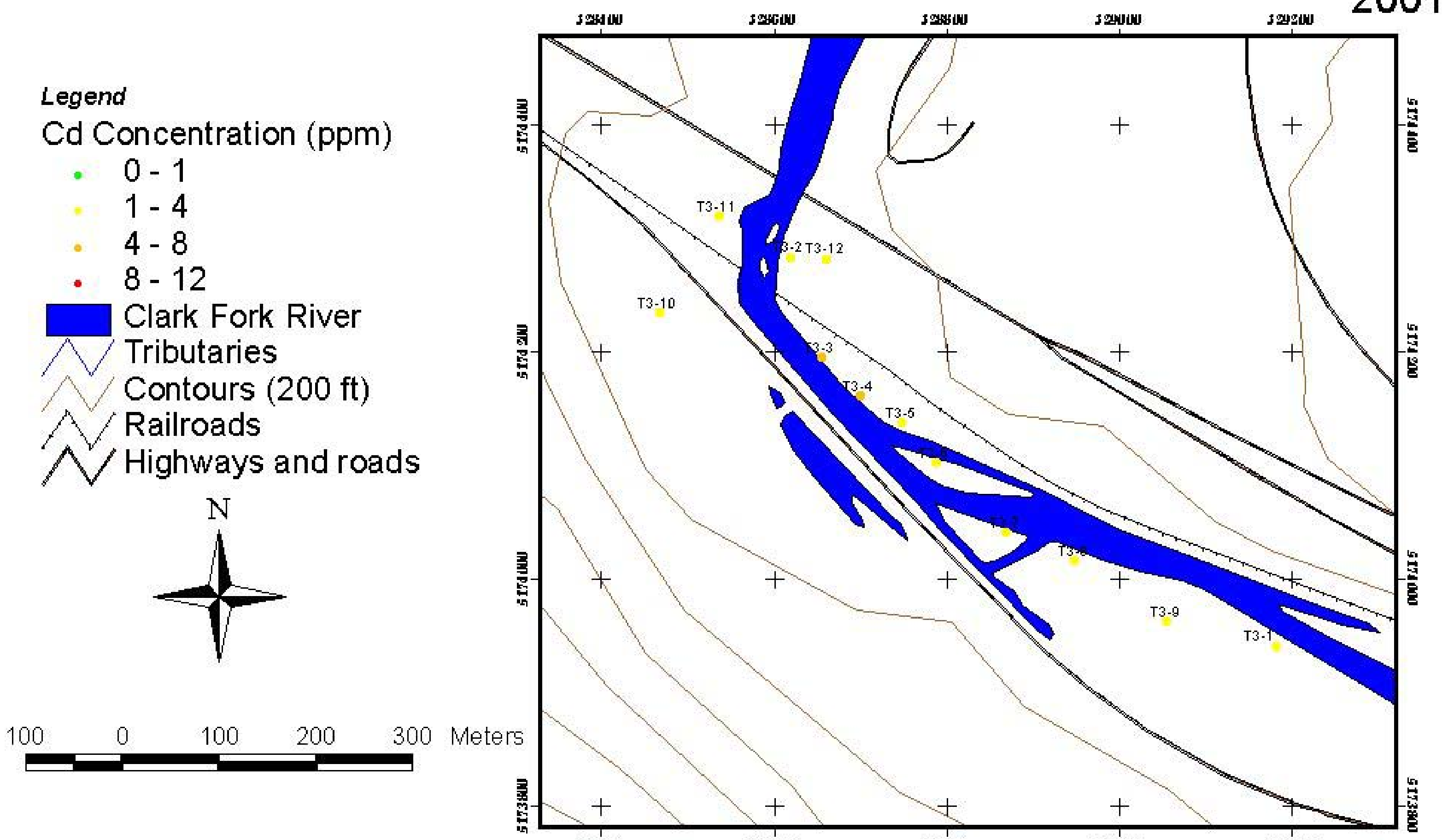


Figure III-16

Cadmium Concentrations (ppm)

Tract 3
2001



UTM 12 North, NAD 1983, HPGN (Idaho/Montana)

Figure III-17

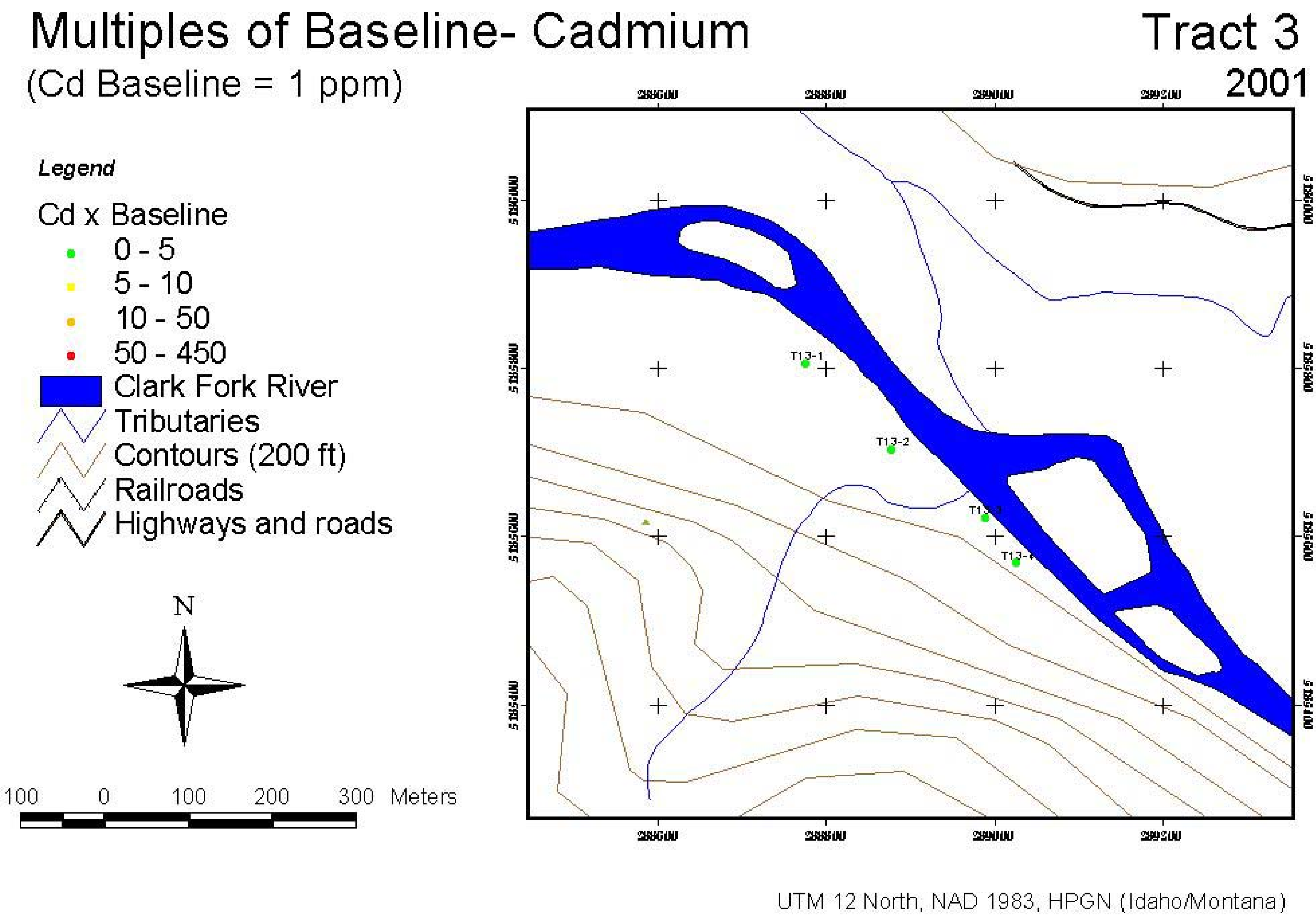


Figure III-18

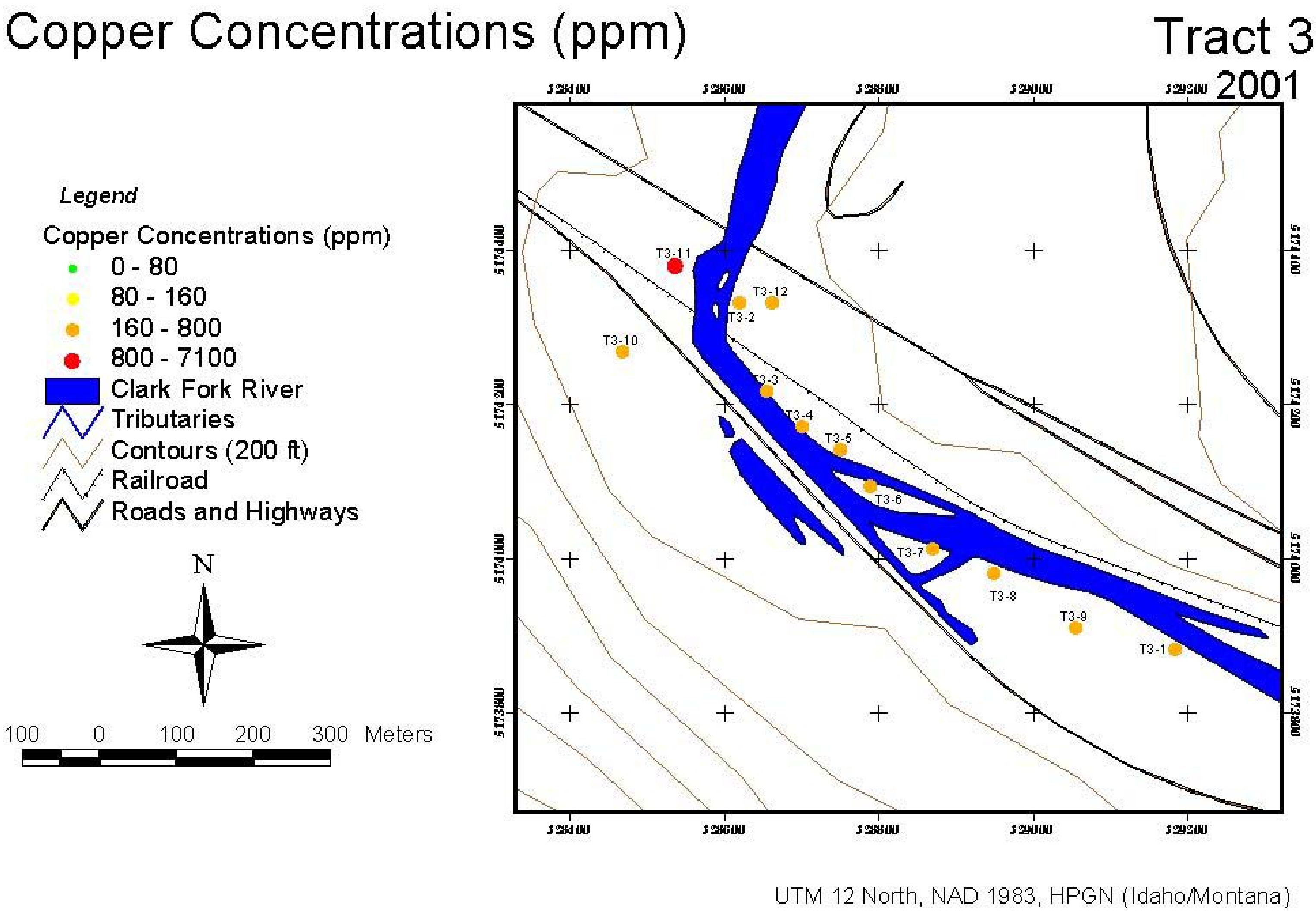


Figure III-19

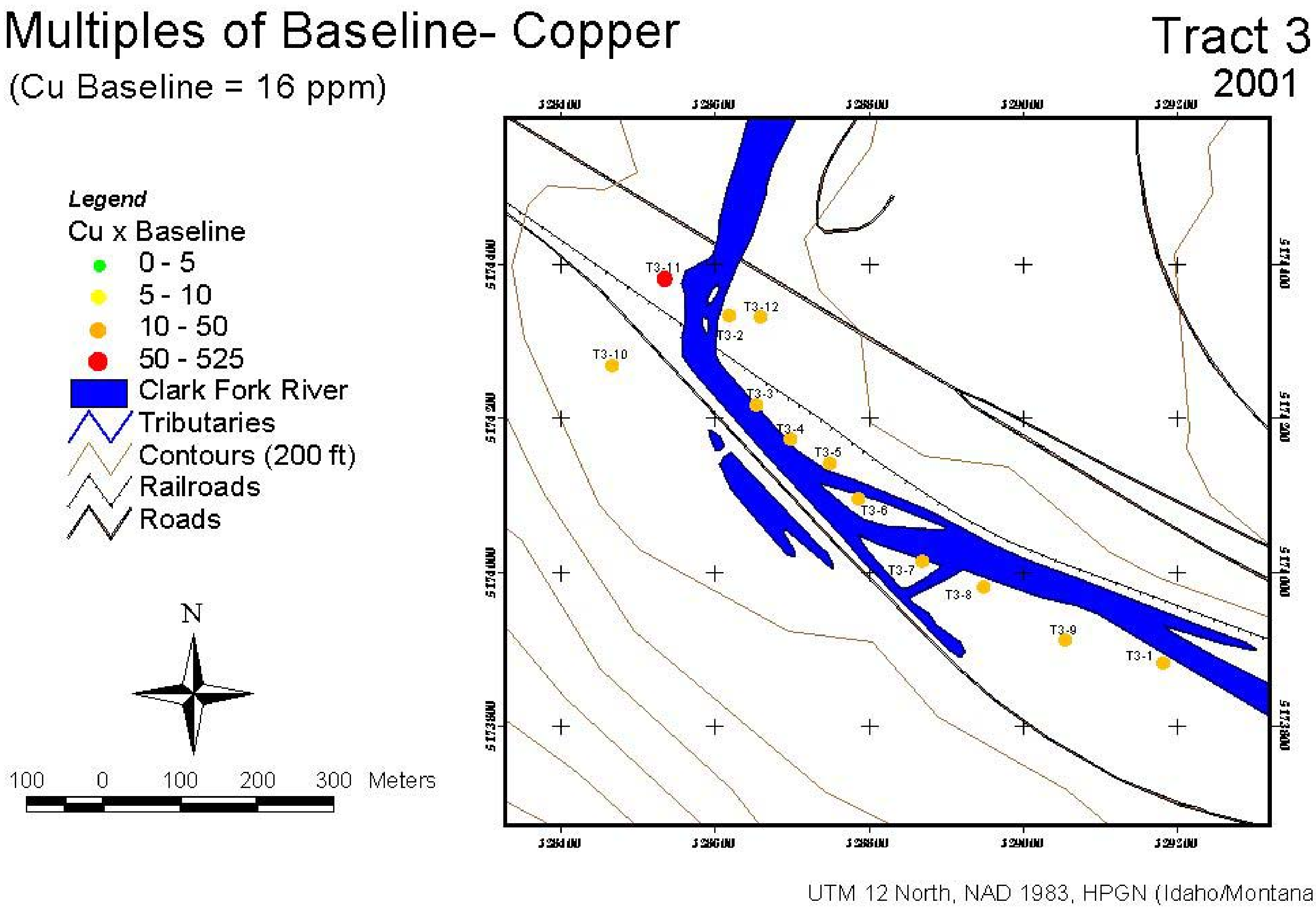


Figure III-20

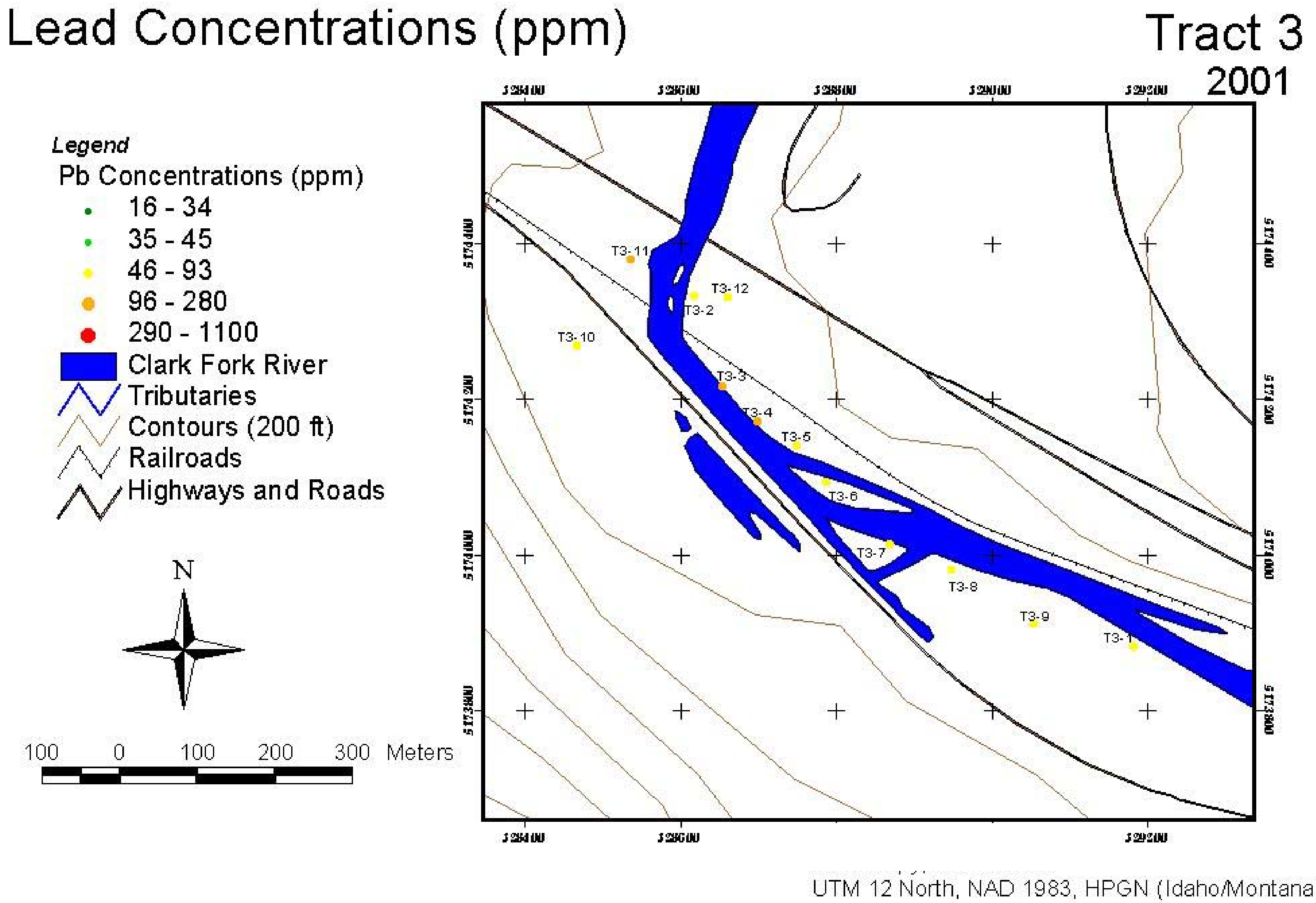


Figure III-21

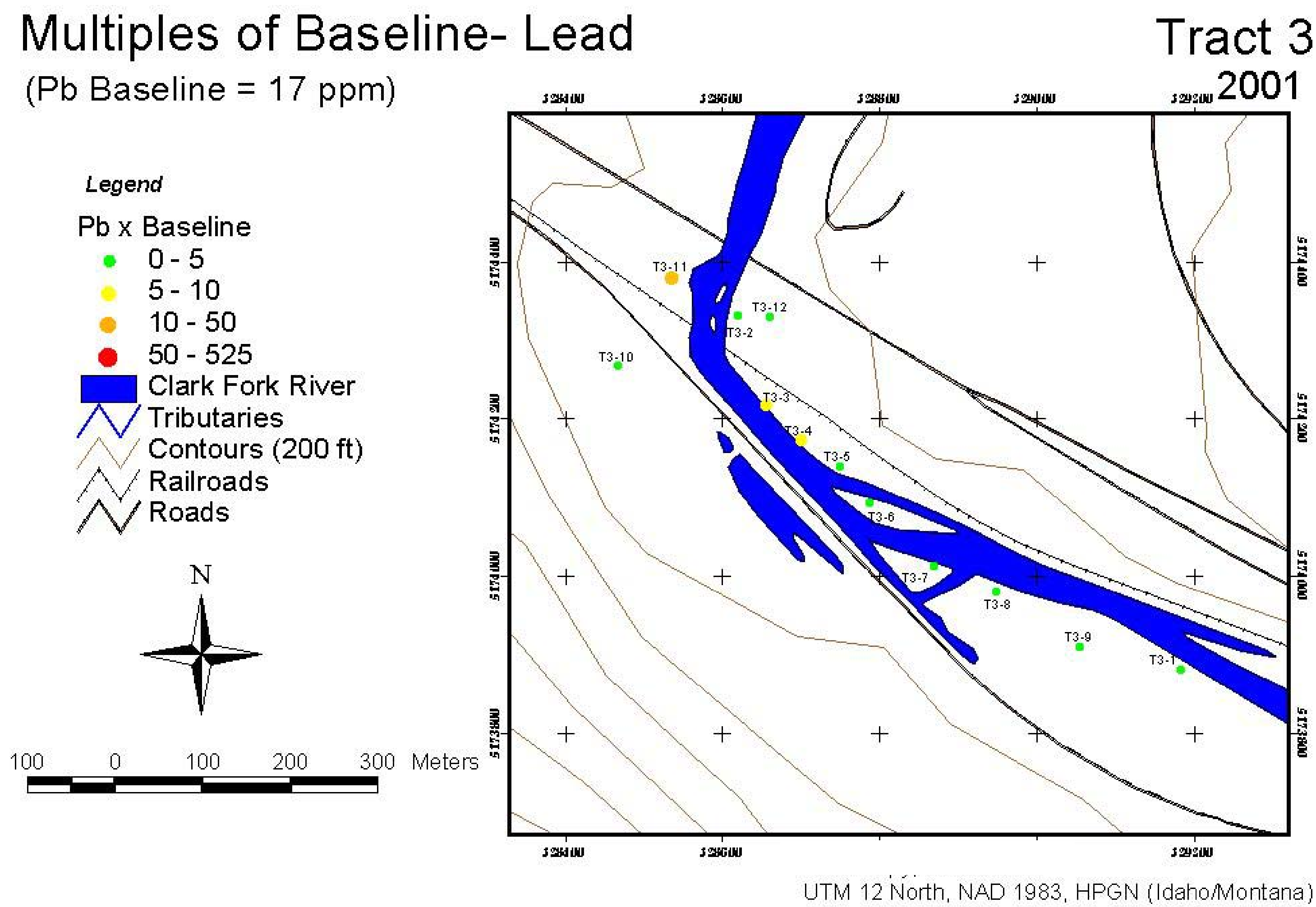


Figure III-22

Zinc Concentrations (ppm)

Tract 3
2001

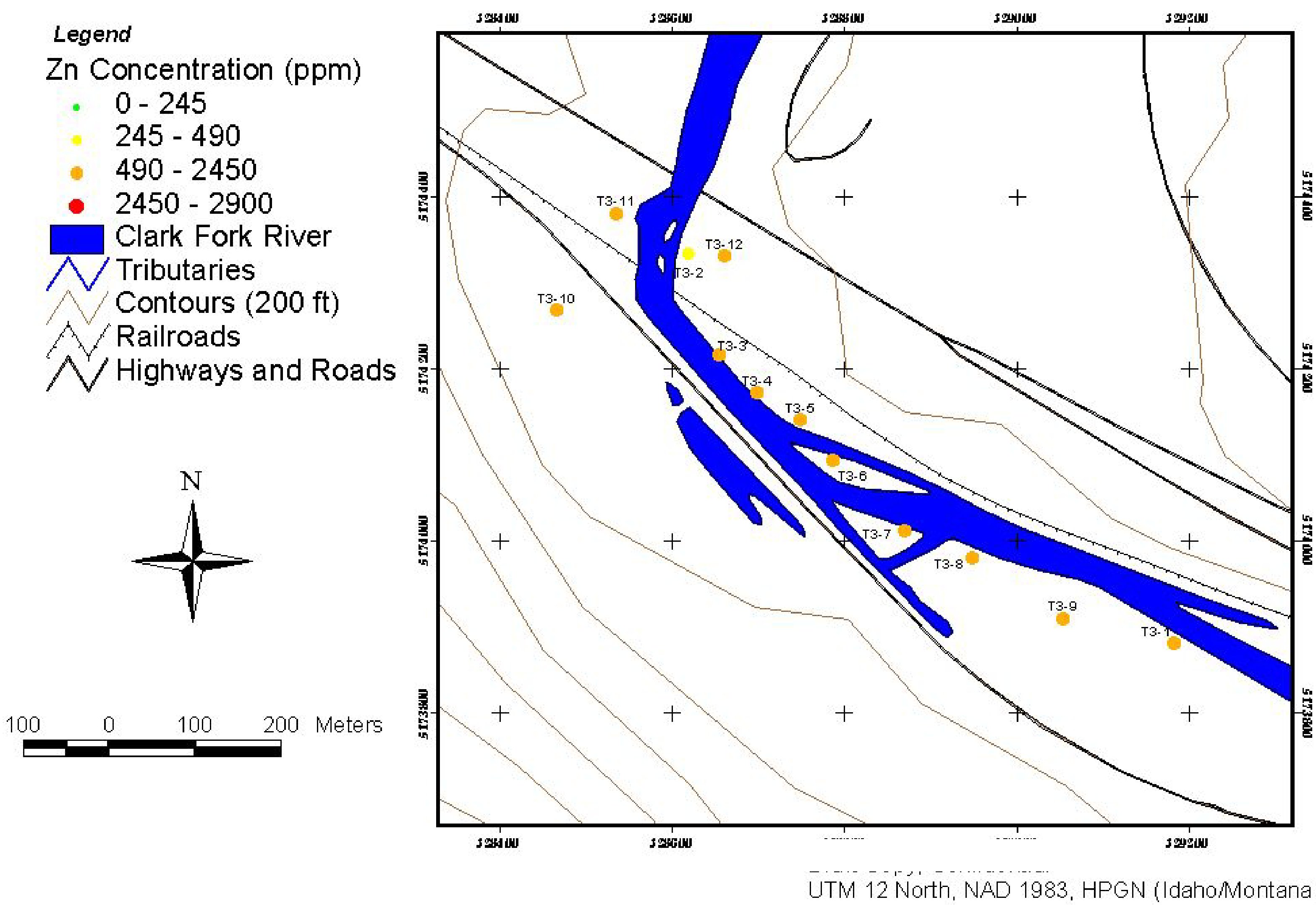


Figure III-23

Multiples of Baseline- Zinc

(Zn Baseline = 49 ppm)

Tract 3
2001

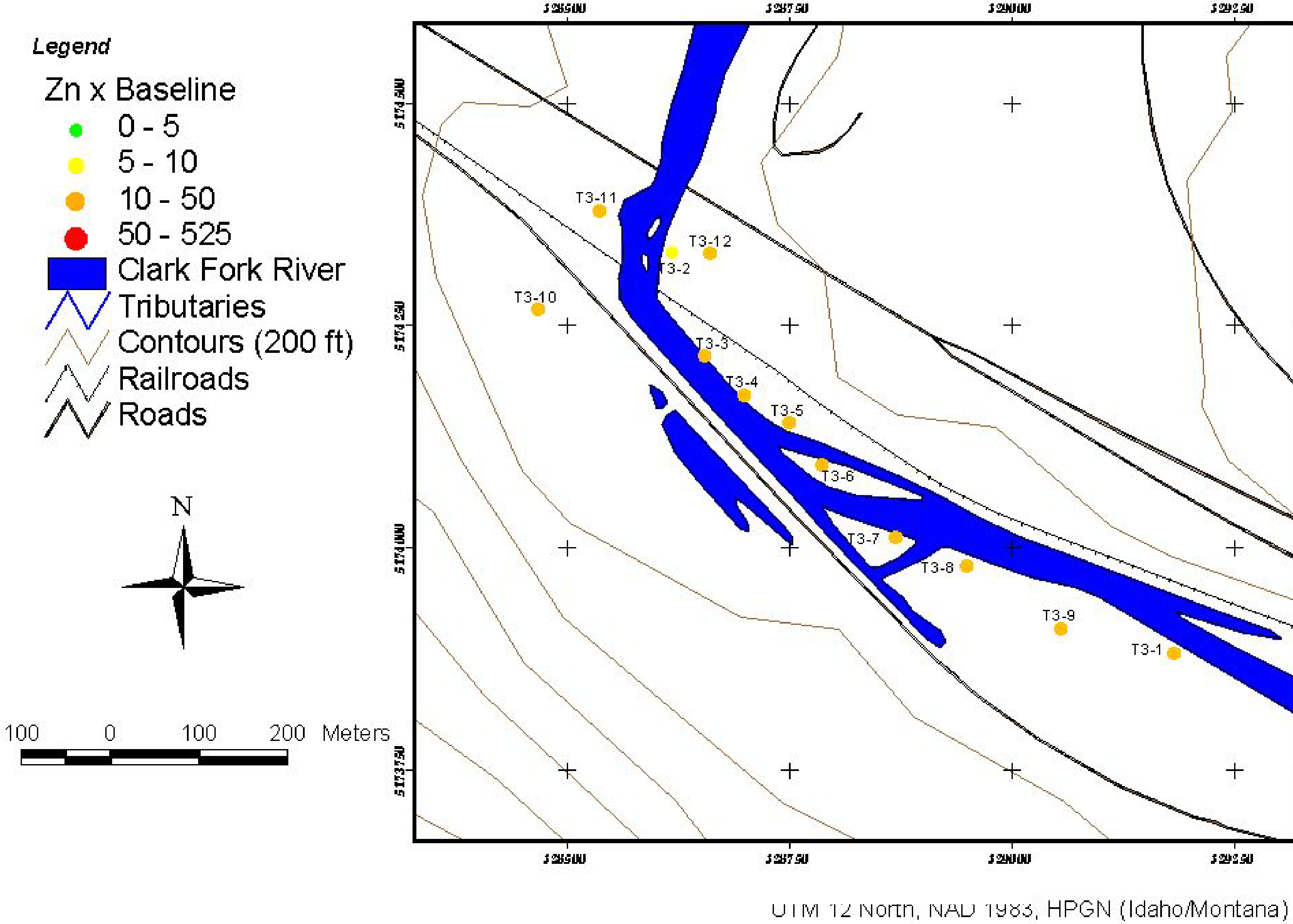
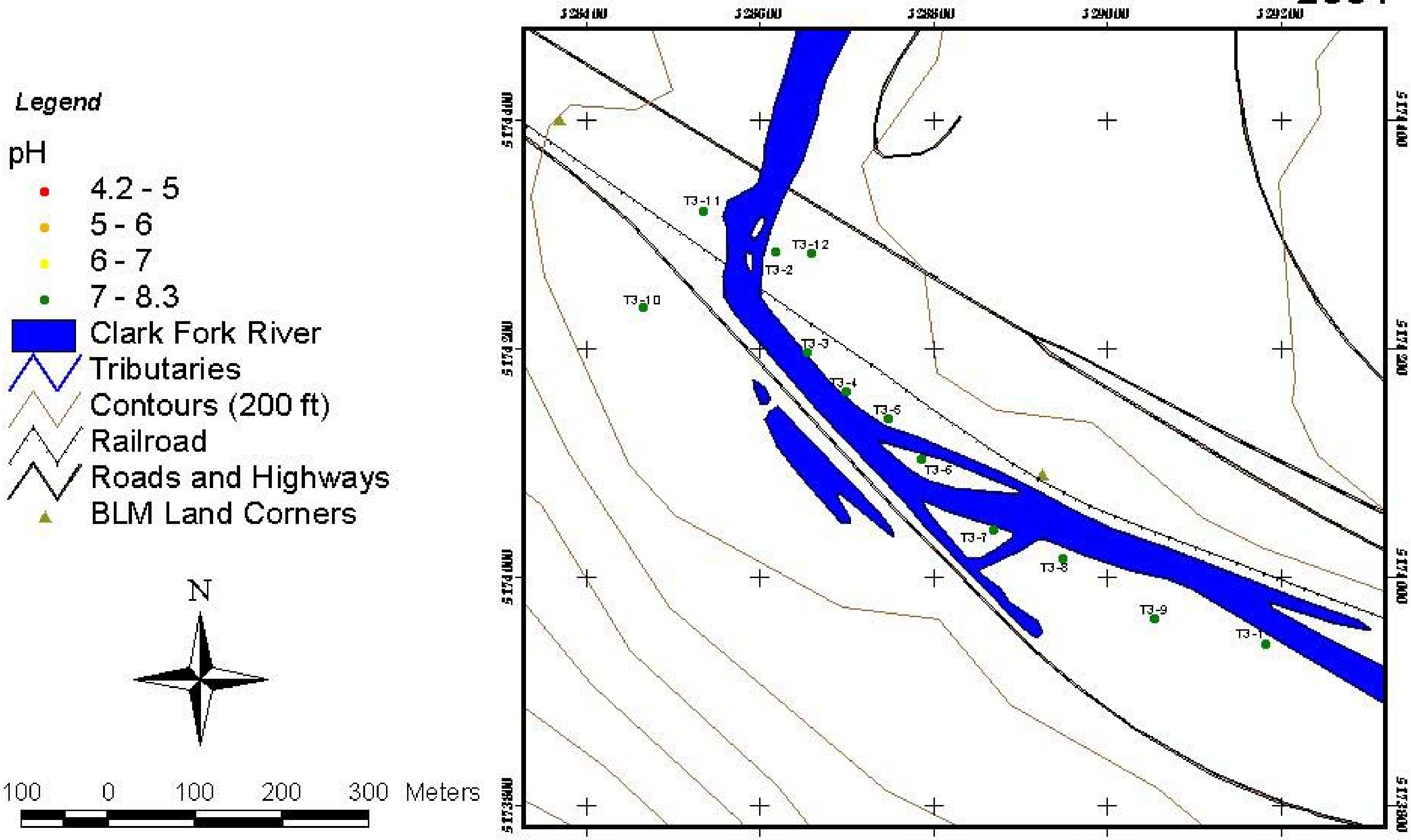


Figure III-24

pH

Tract 3
2001



UTM 12 North, NAD 1983, HPGN (Idaho/Montana)

Figure III-25

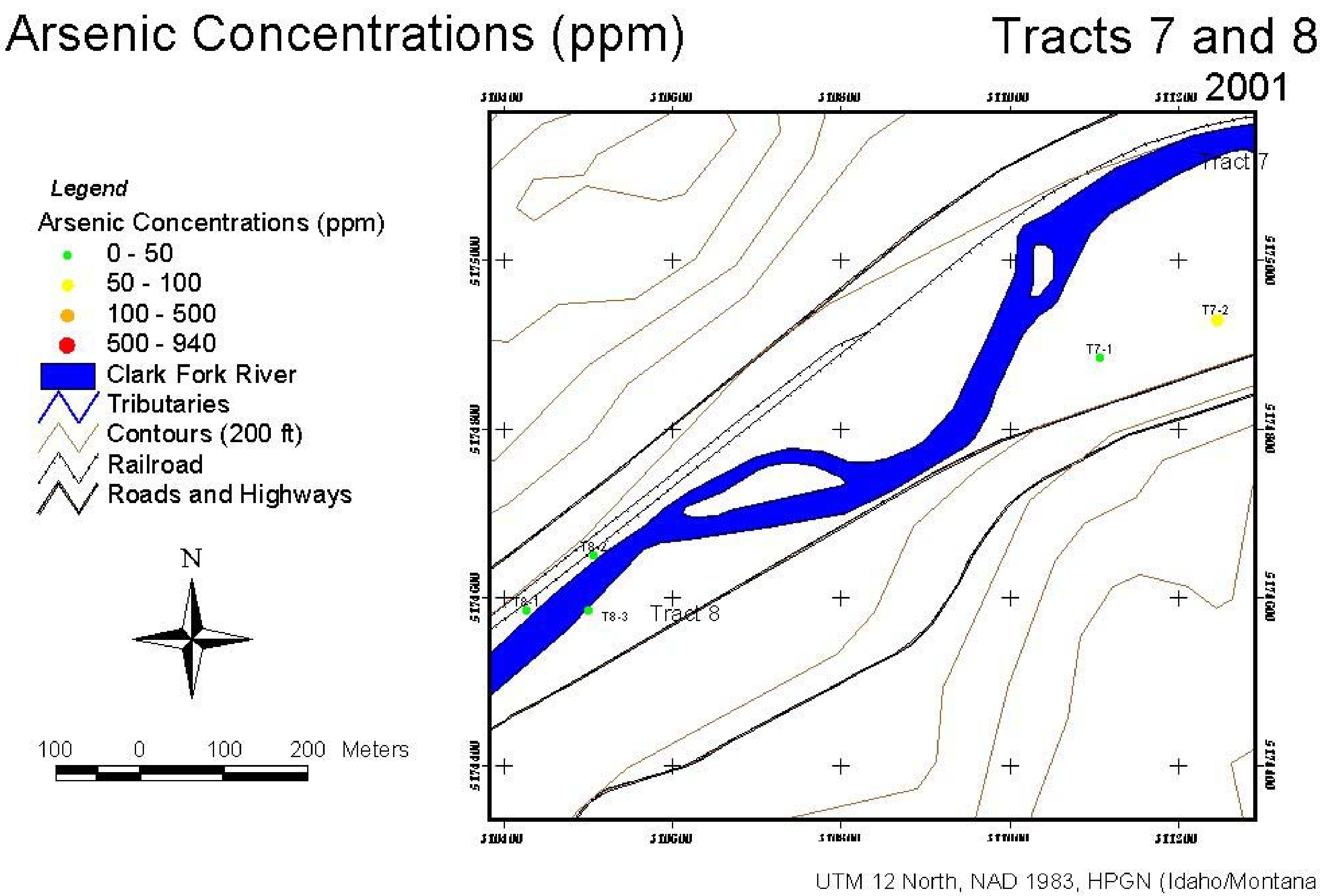


Figure III-26

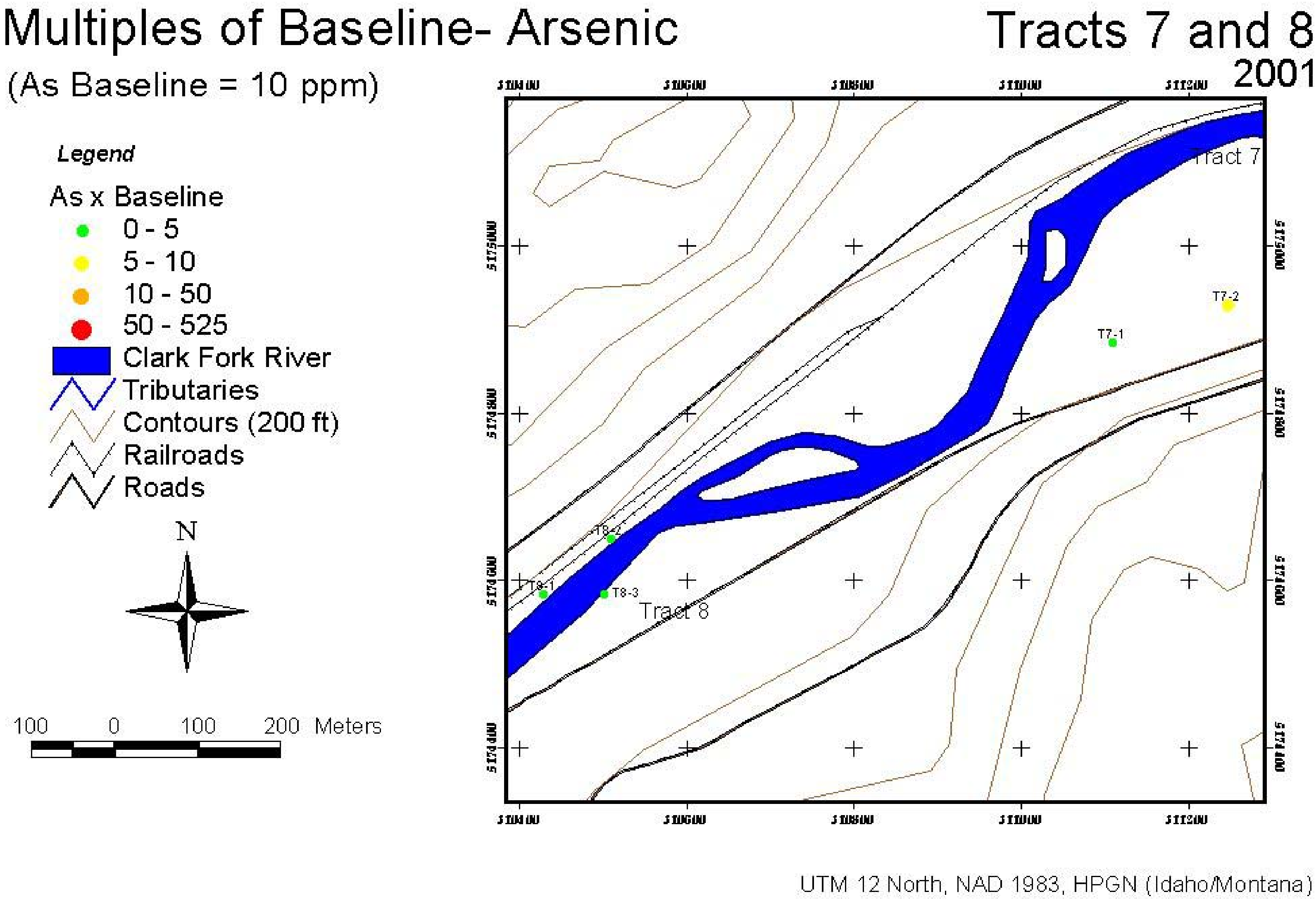


Figure III-27

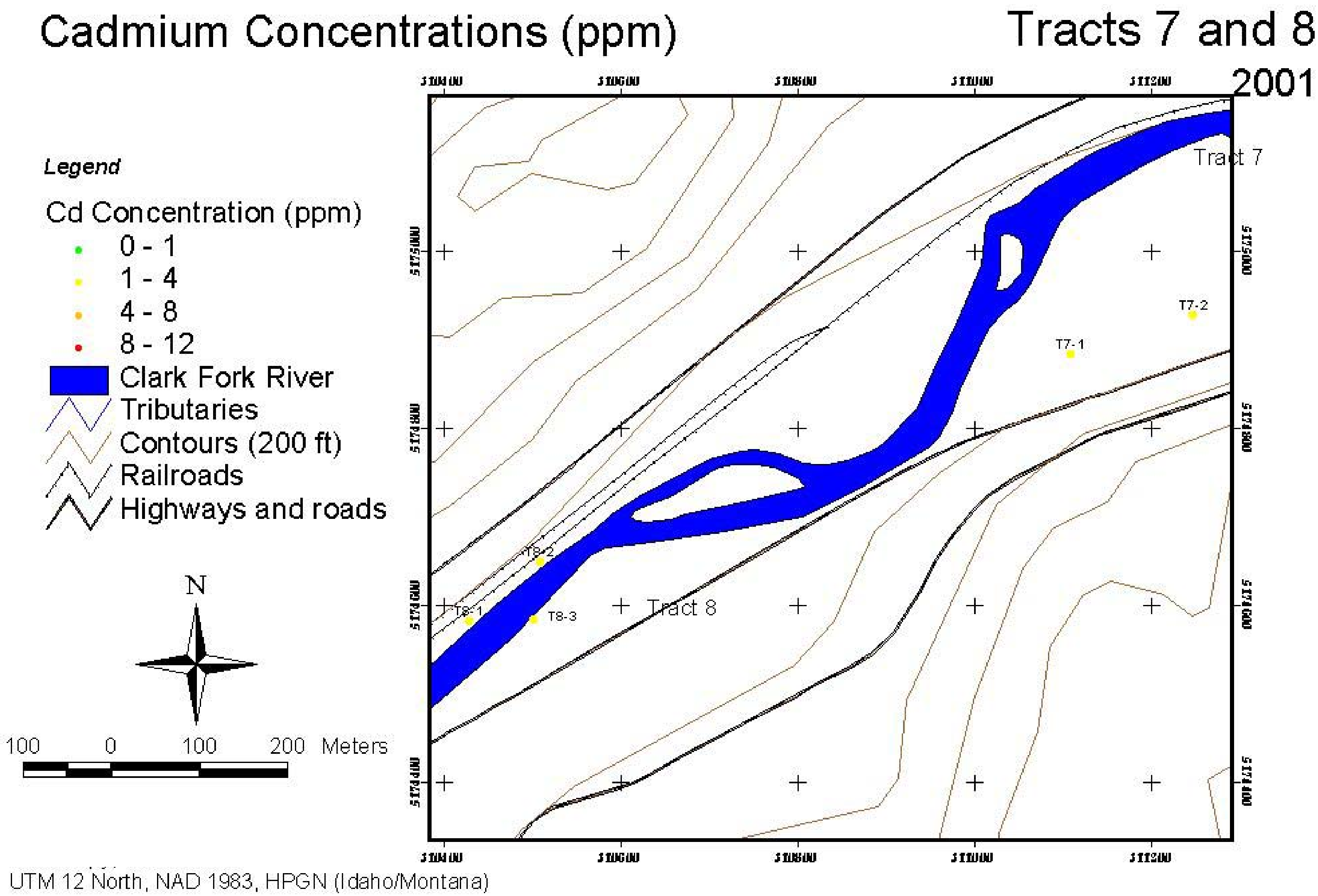


Figure III-28

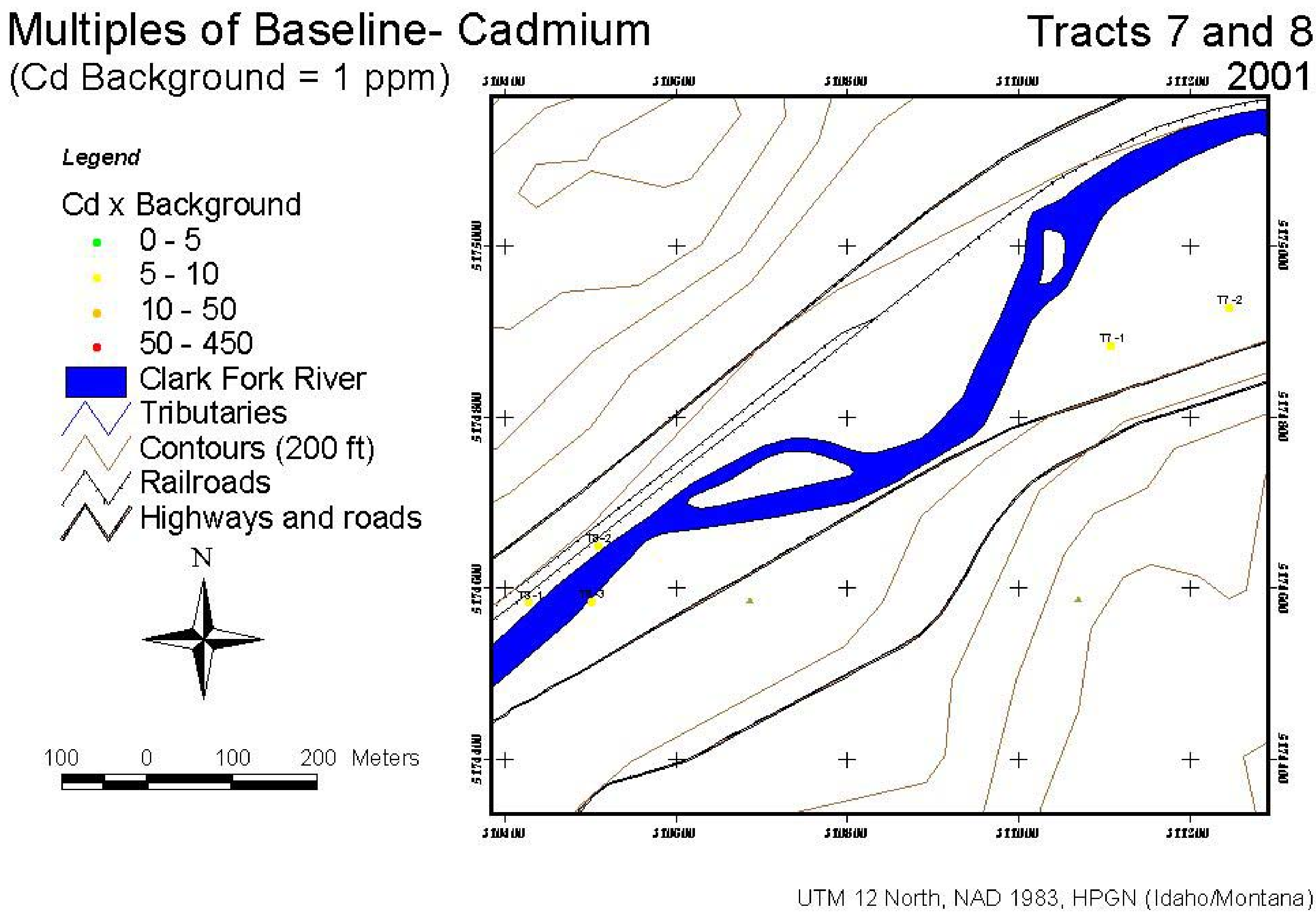


Figure III-29

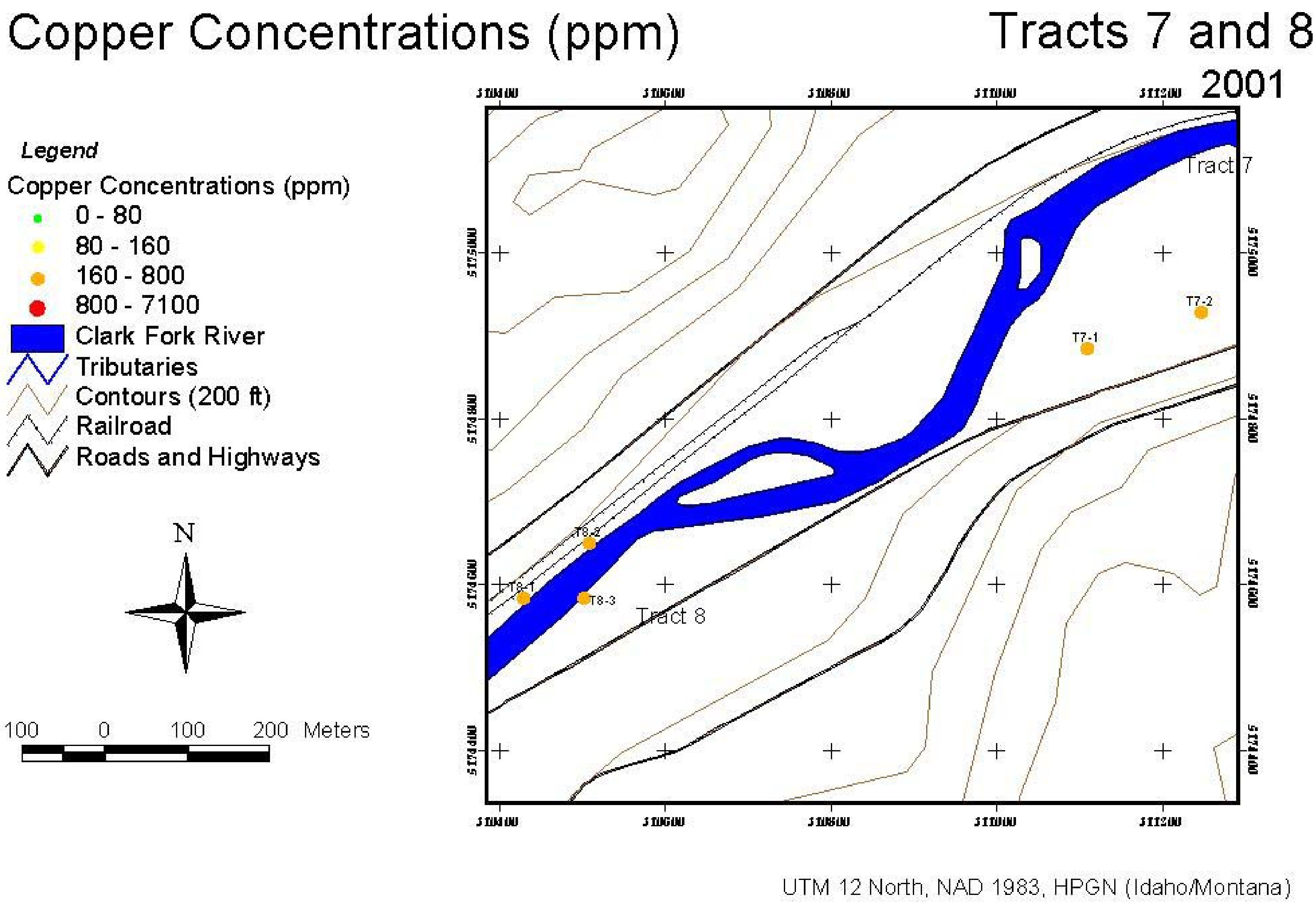


Figure III-30

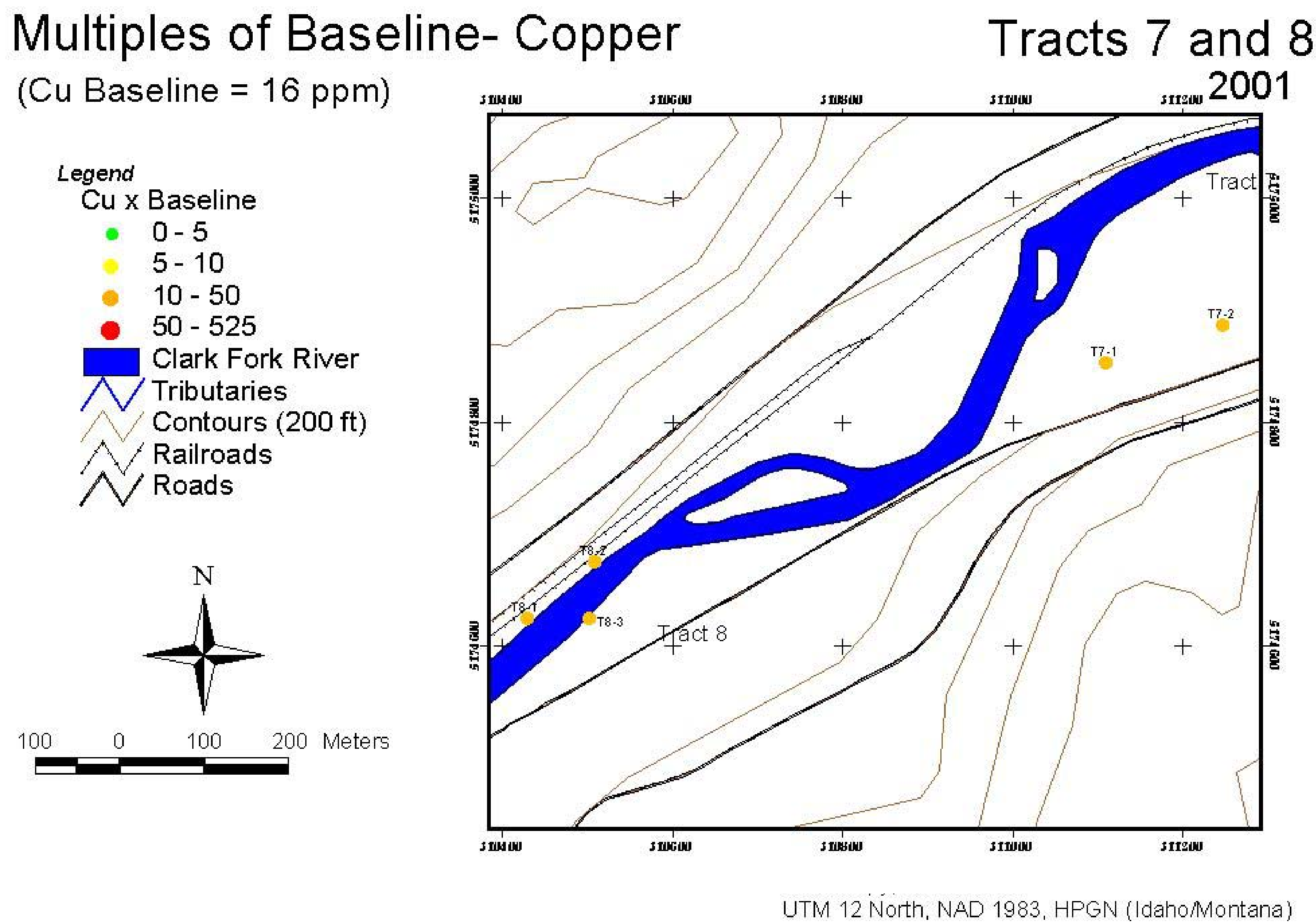


Figure III-31

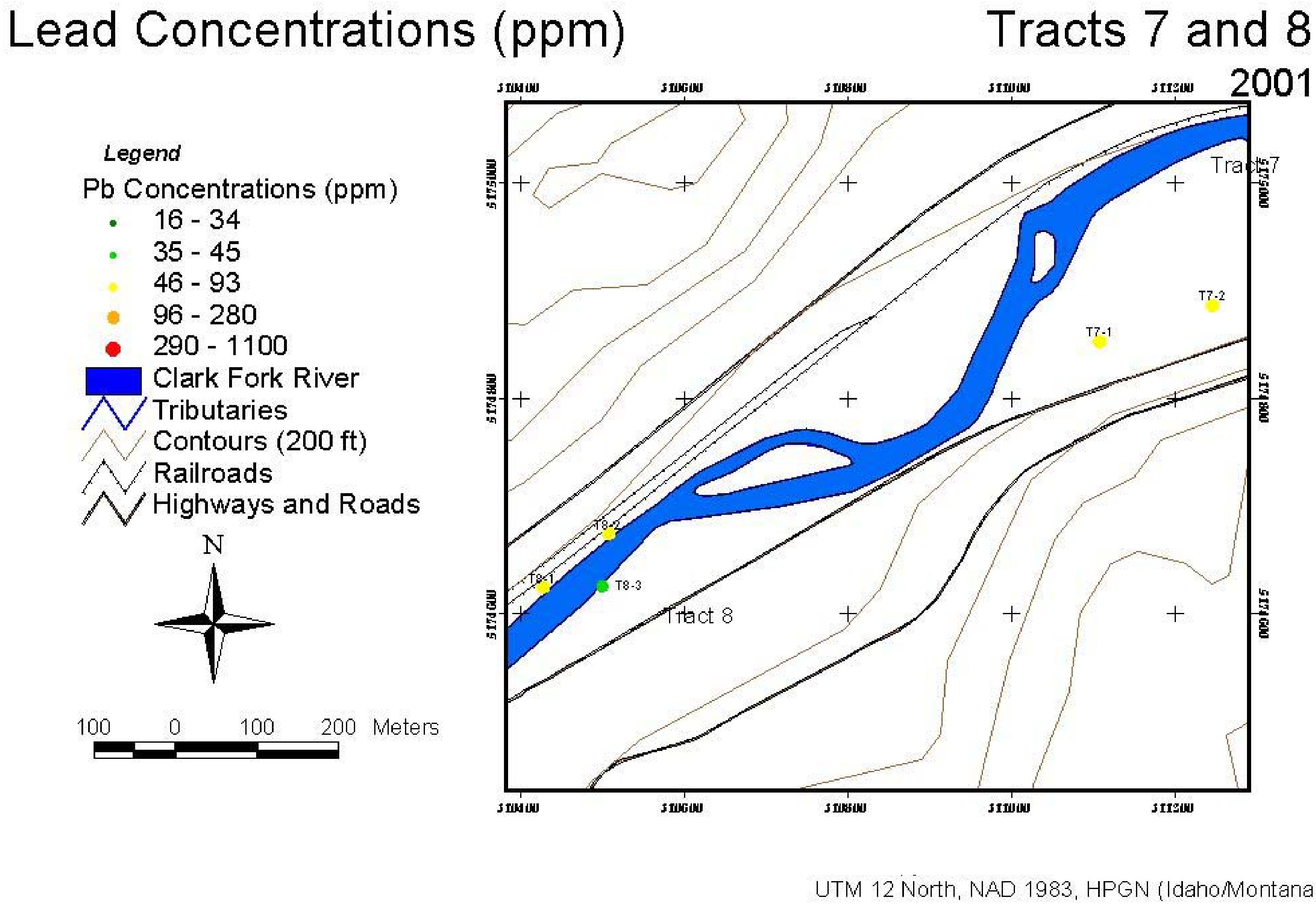


Figure III-32

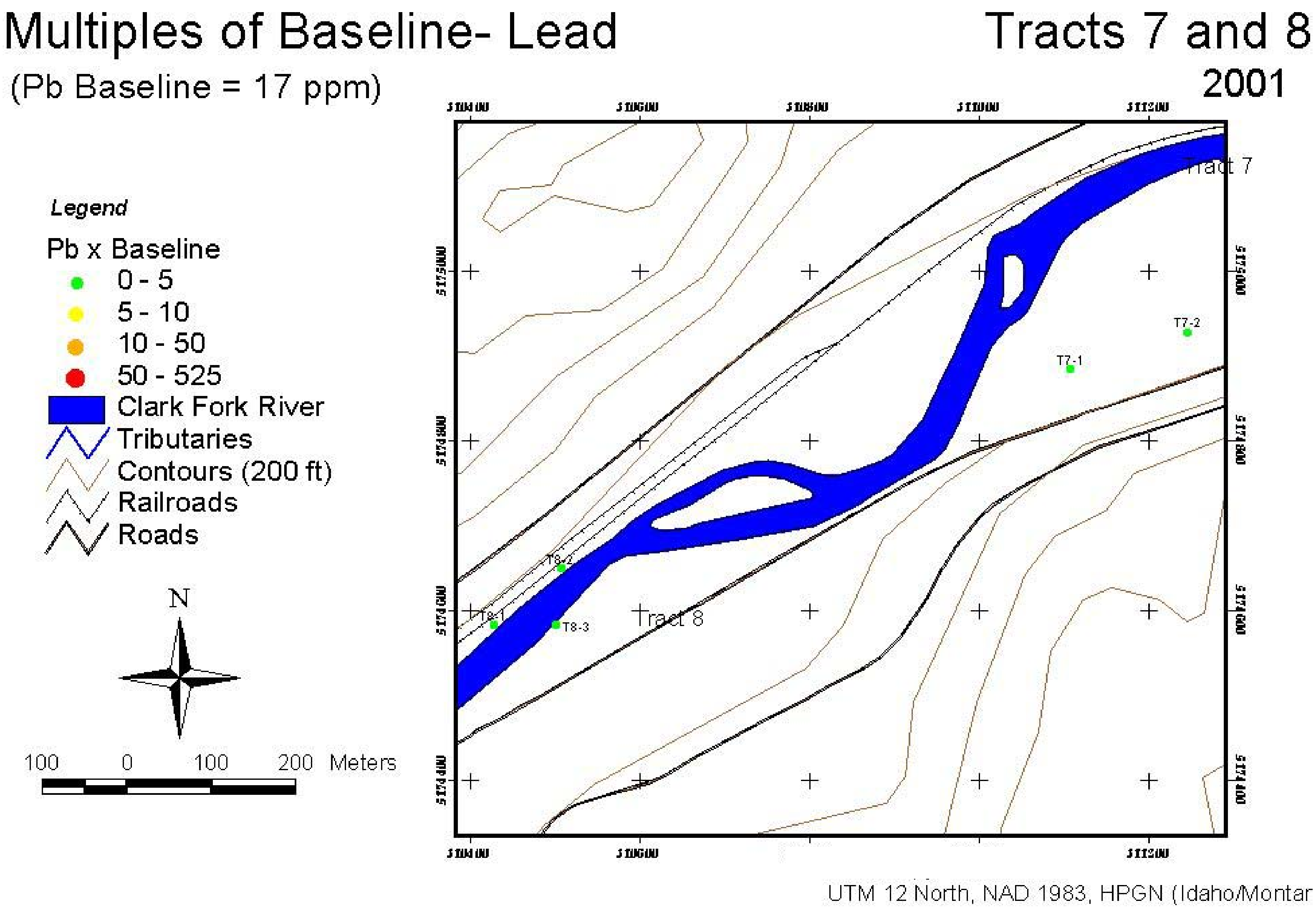


Figure III-33

Zinc Concentrations (ppm)

Tracts 7 and 8

2001

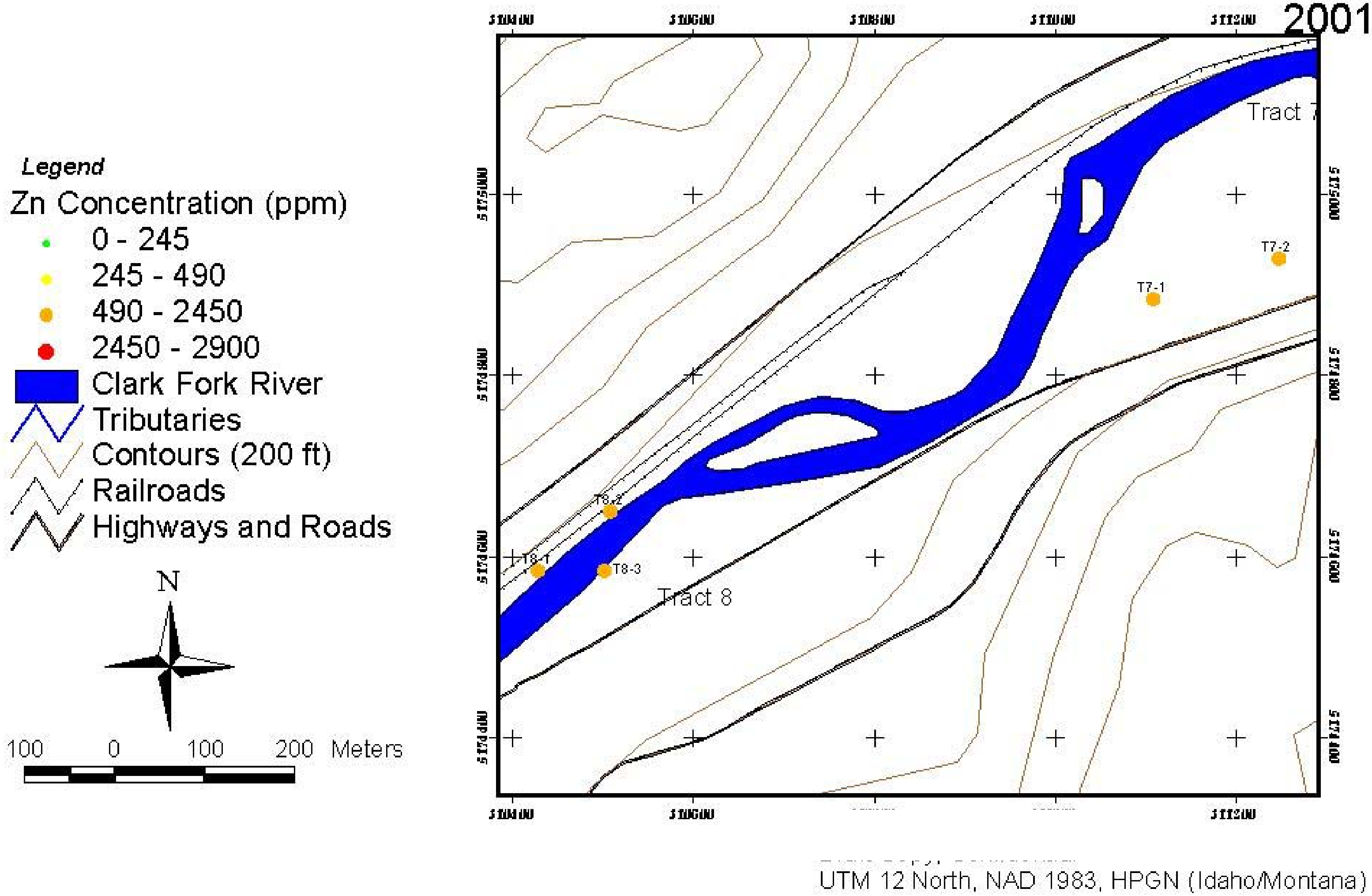


Figure III-34

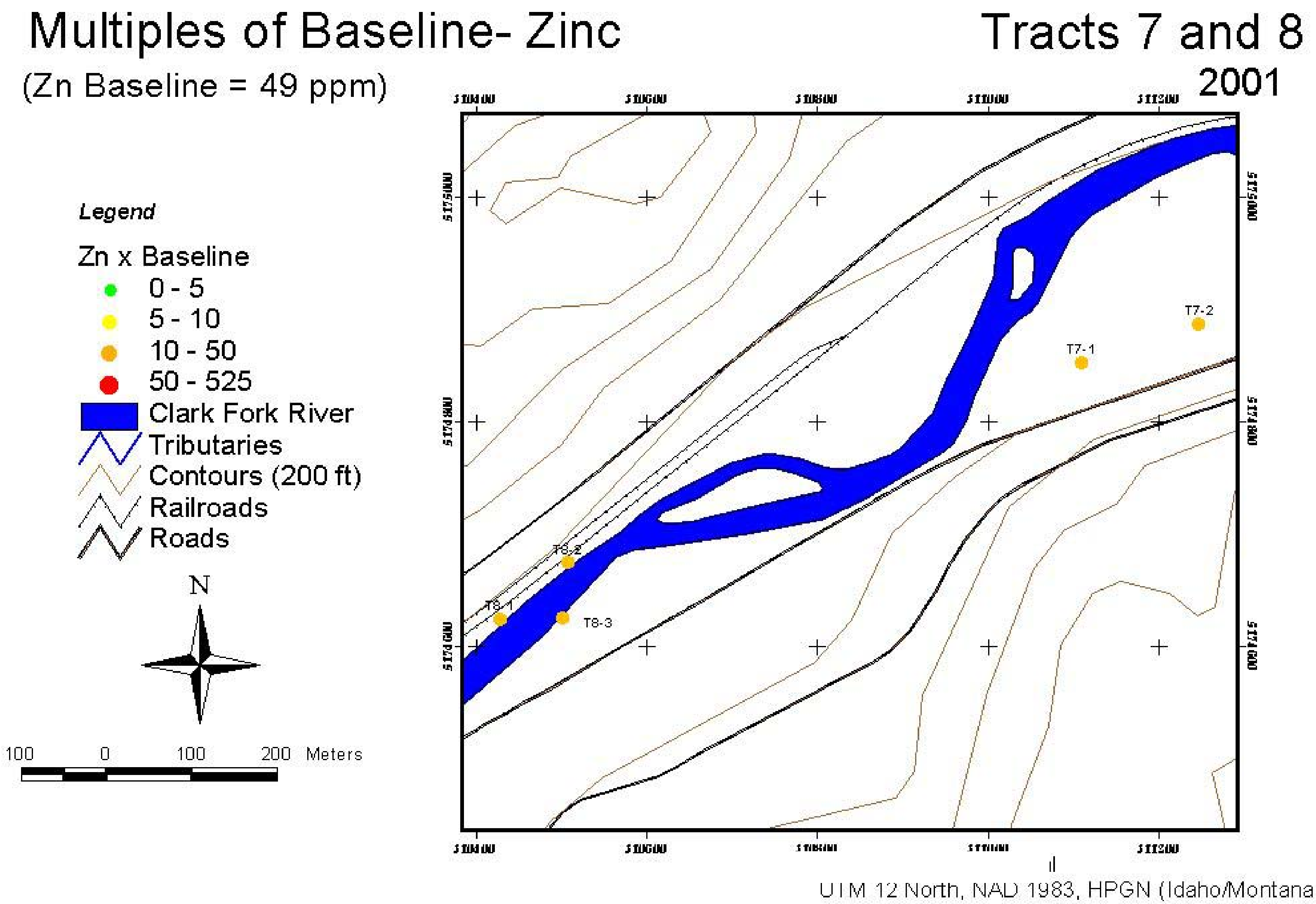


Figure III-35

pH

Tracts 7 and 8
2001

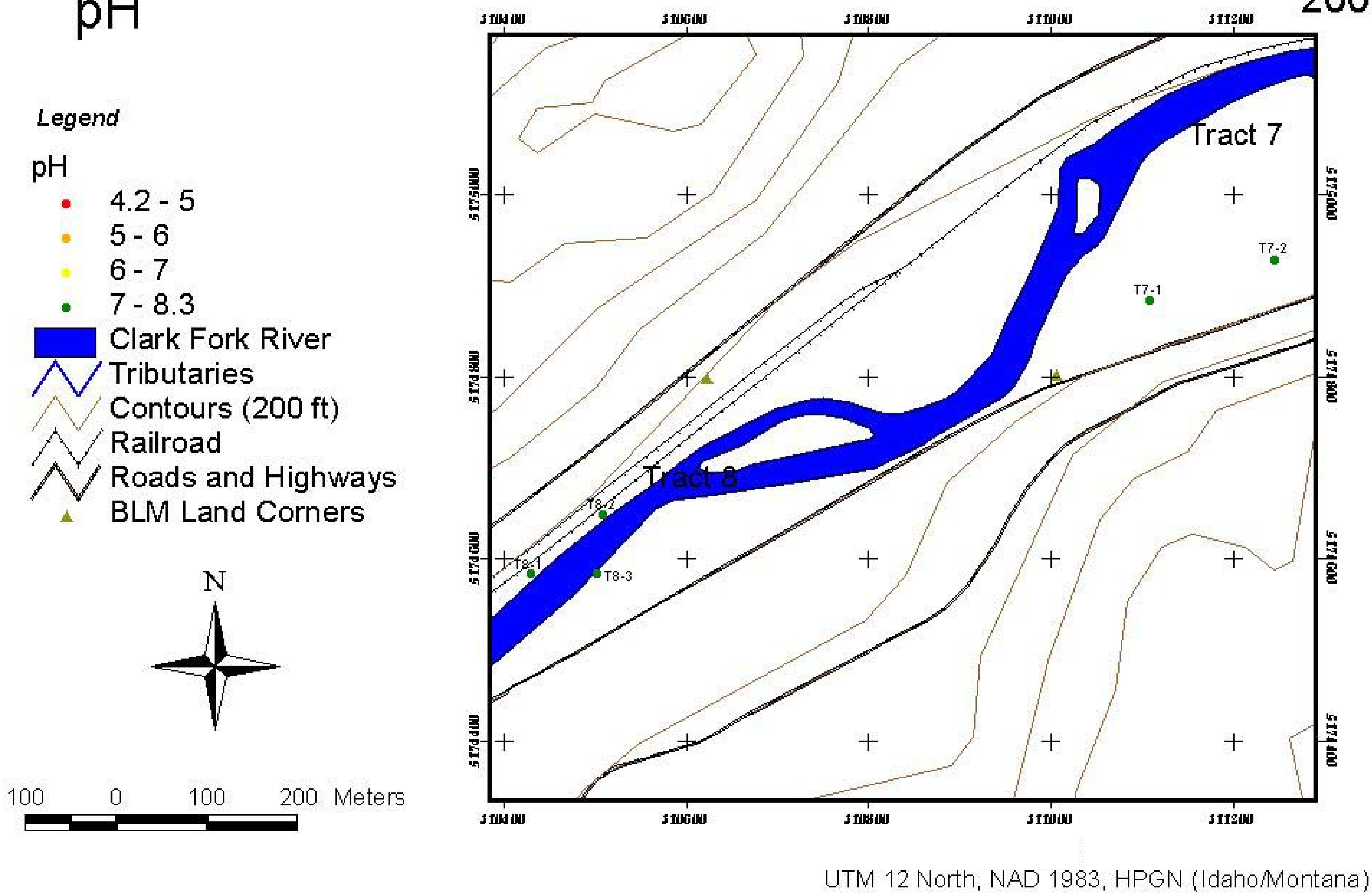


Figure III-36

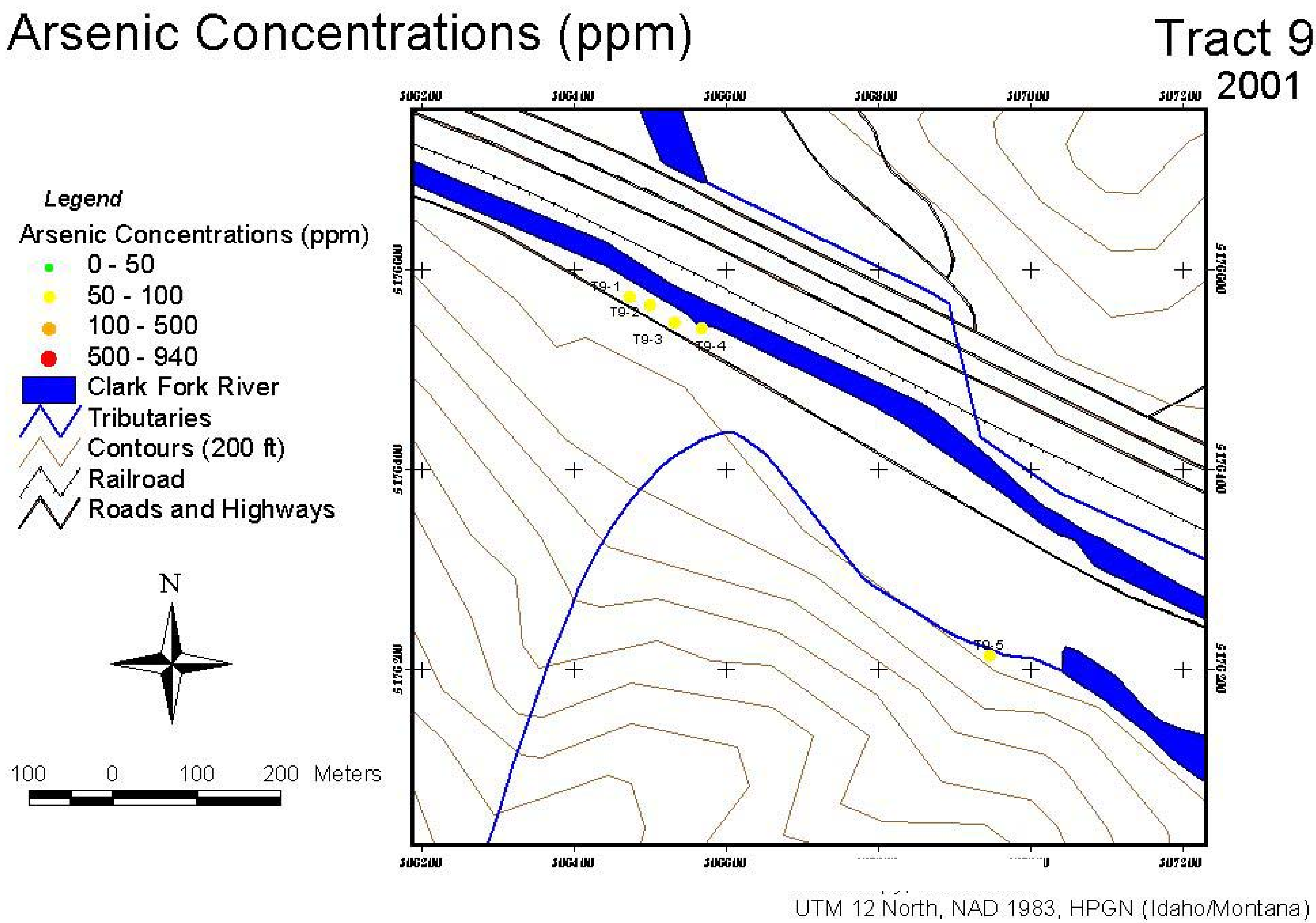


Figure III-37

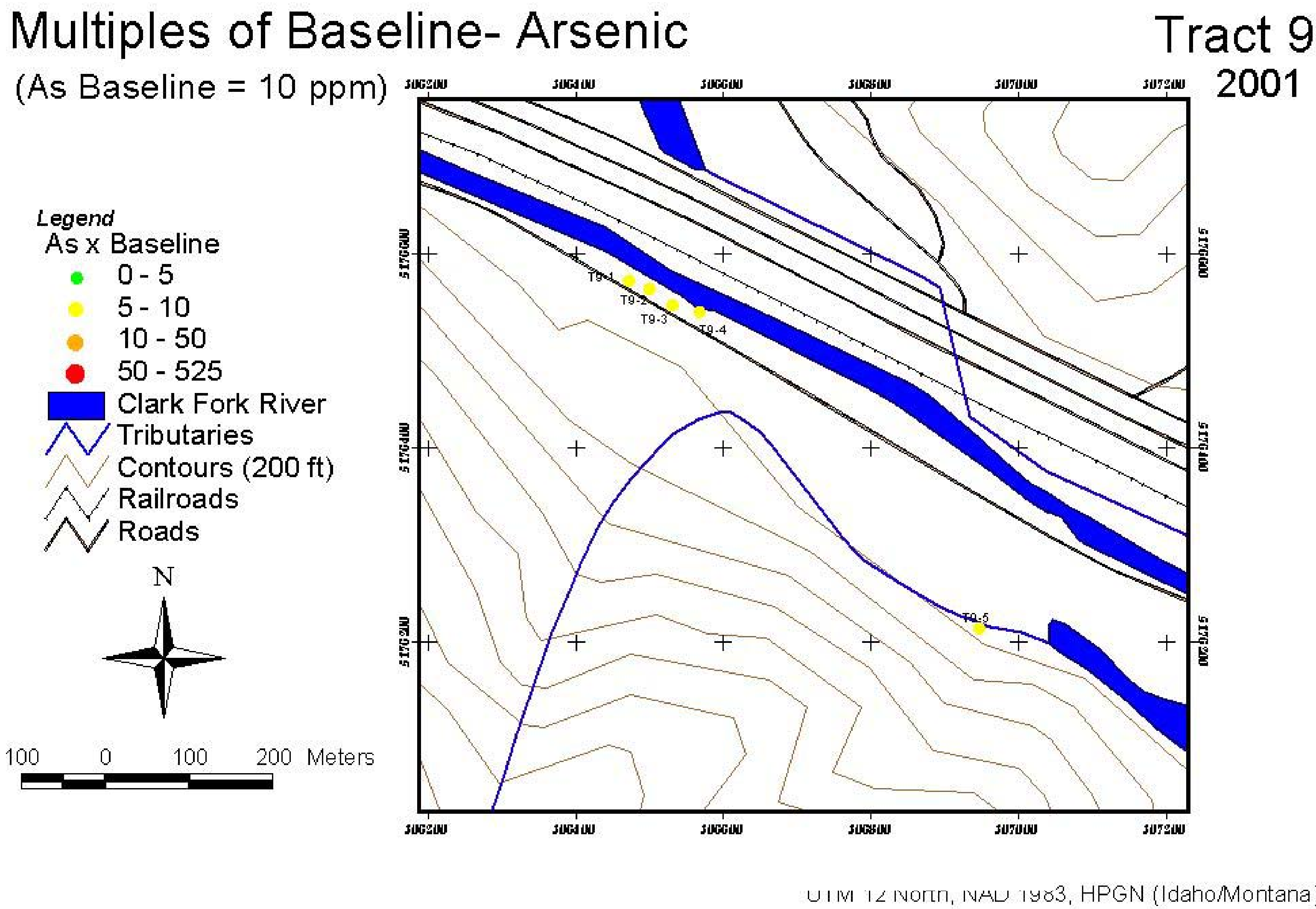


Figure III-38

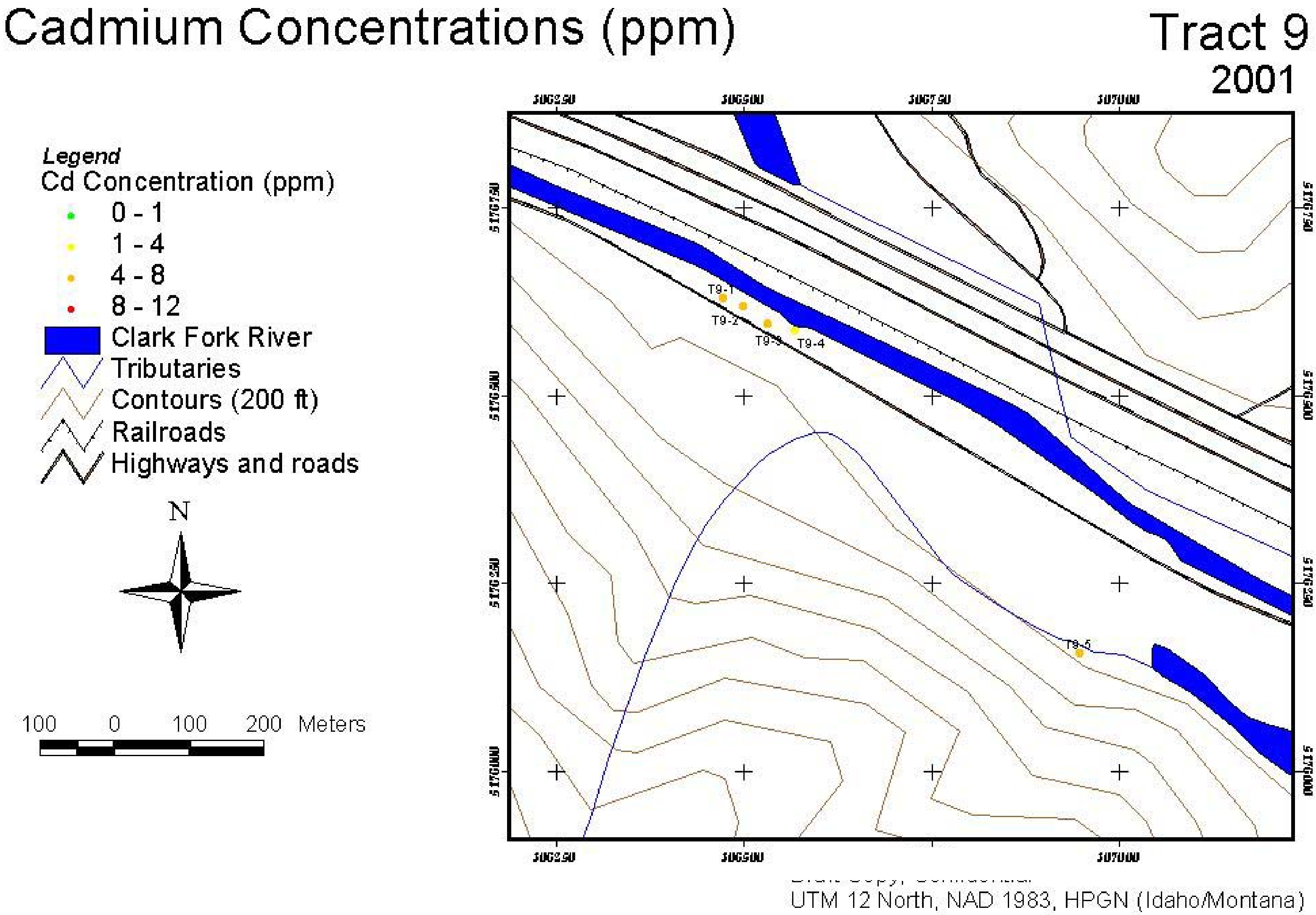


Figure III-39

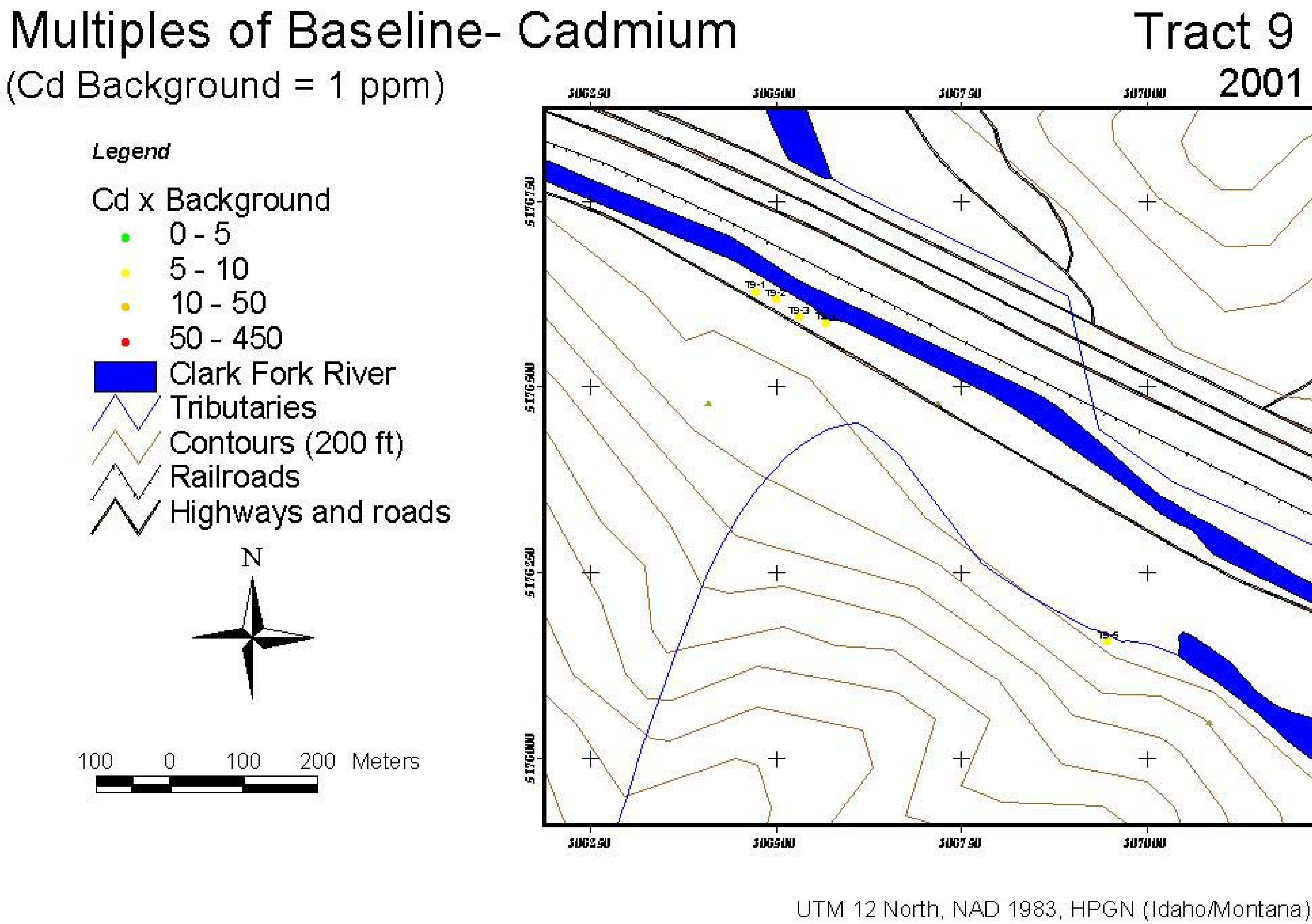


Figure III-40

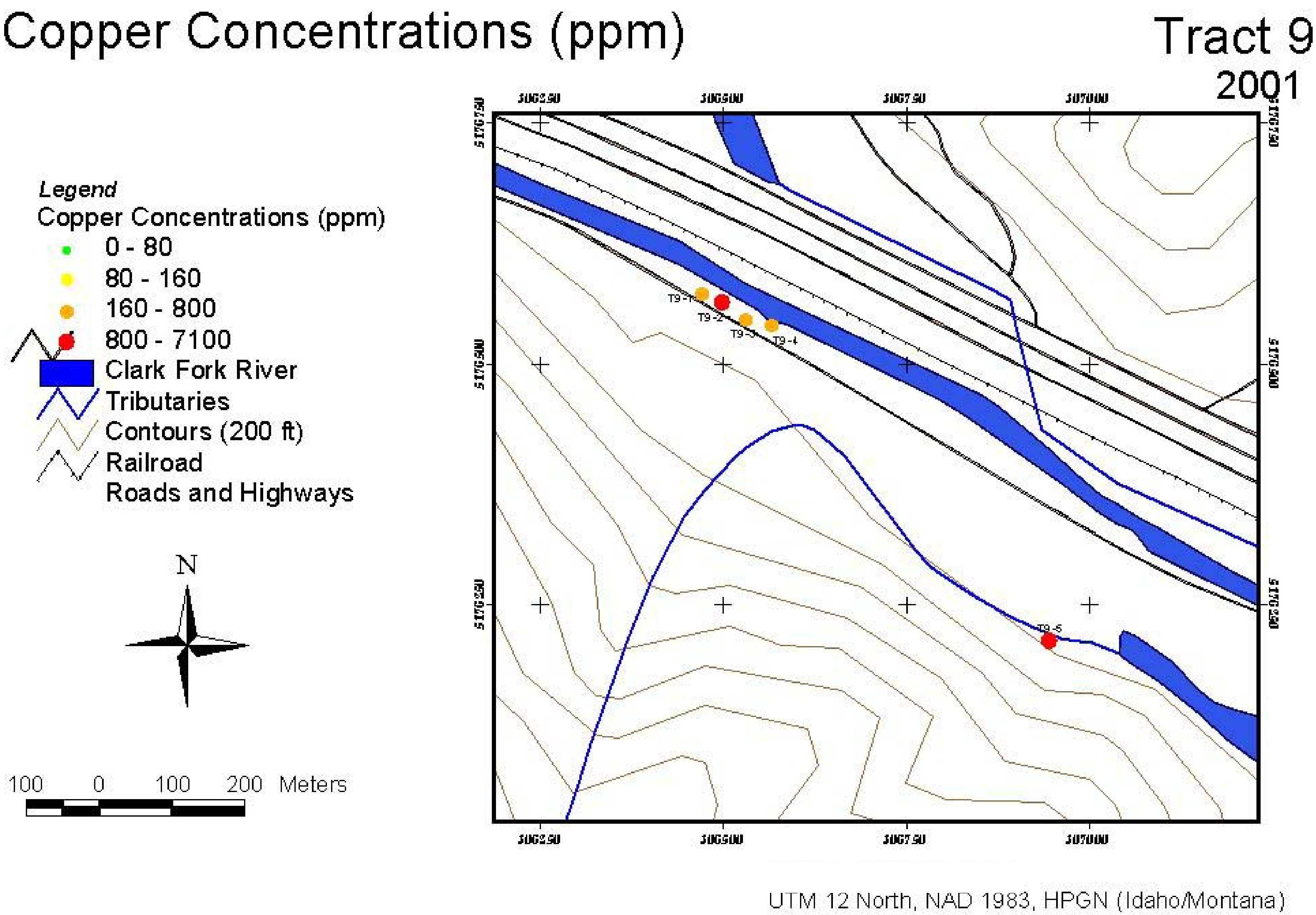
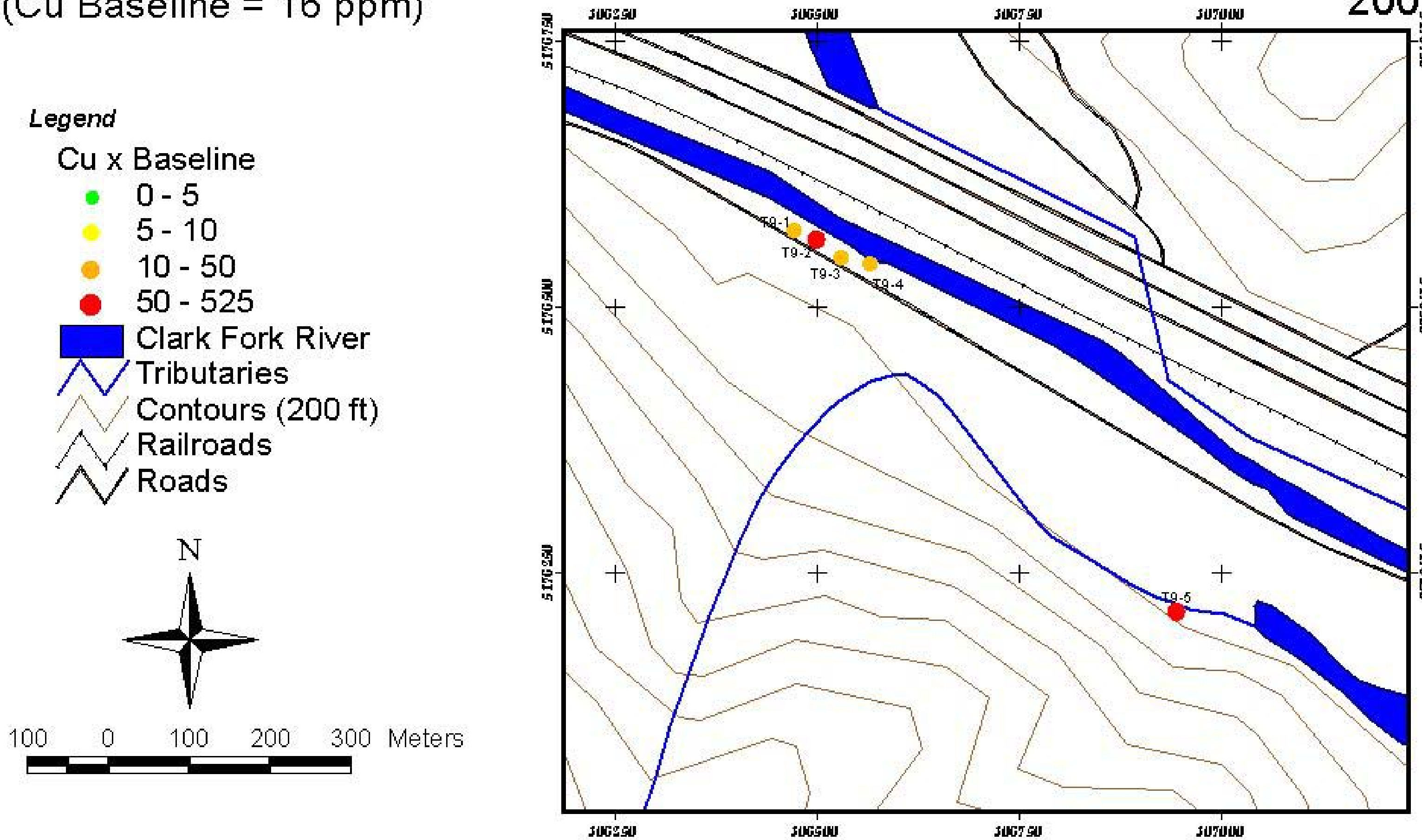


Figure III-41

Multiples of Baseline- Copper

(Cu Baseline = 16 ppm)

Tract 9
2001



UTM 12 North, NAD 1983, HPGN (Idaho/Montana)

Figure III-42

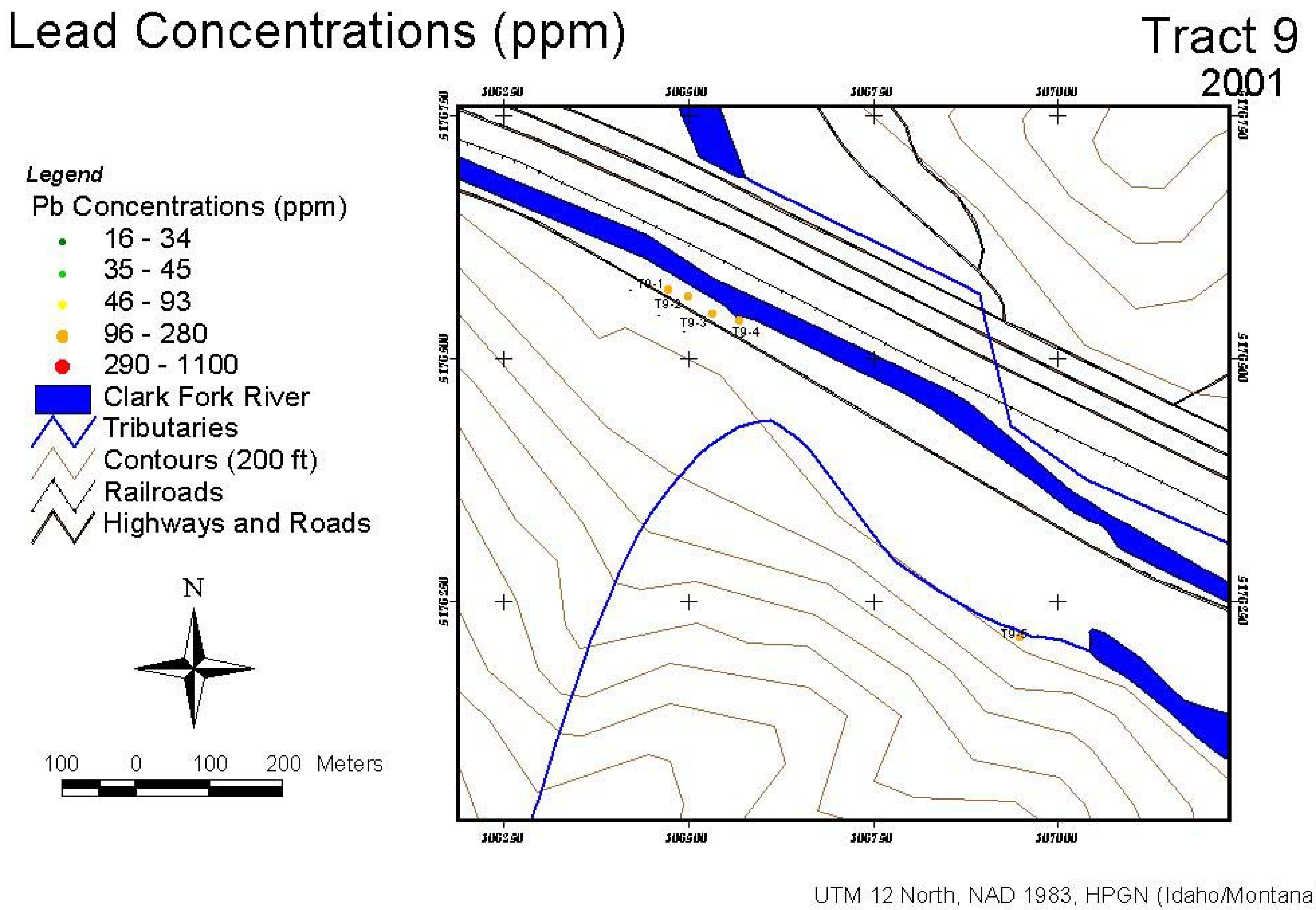


Figure III-43

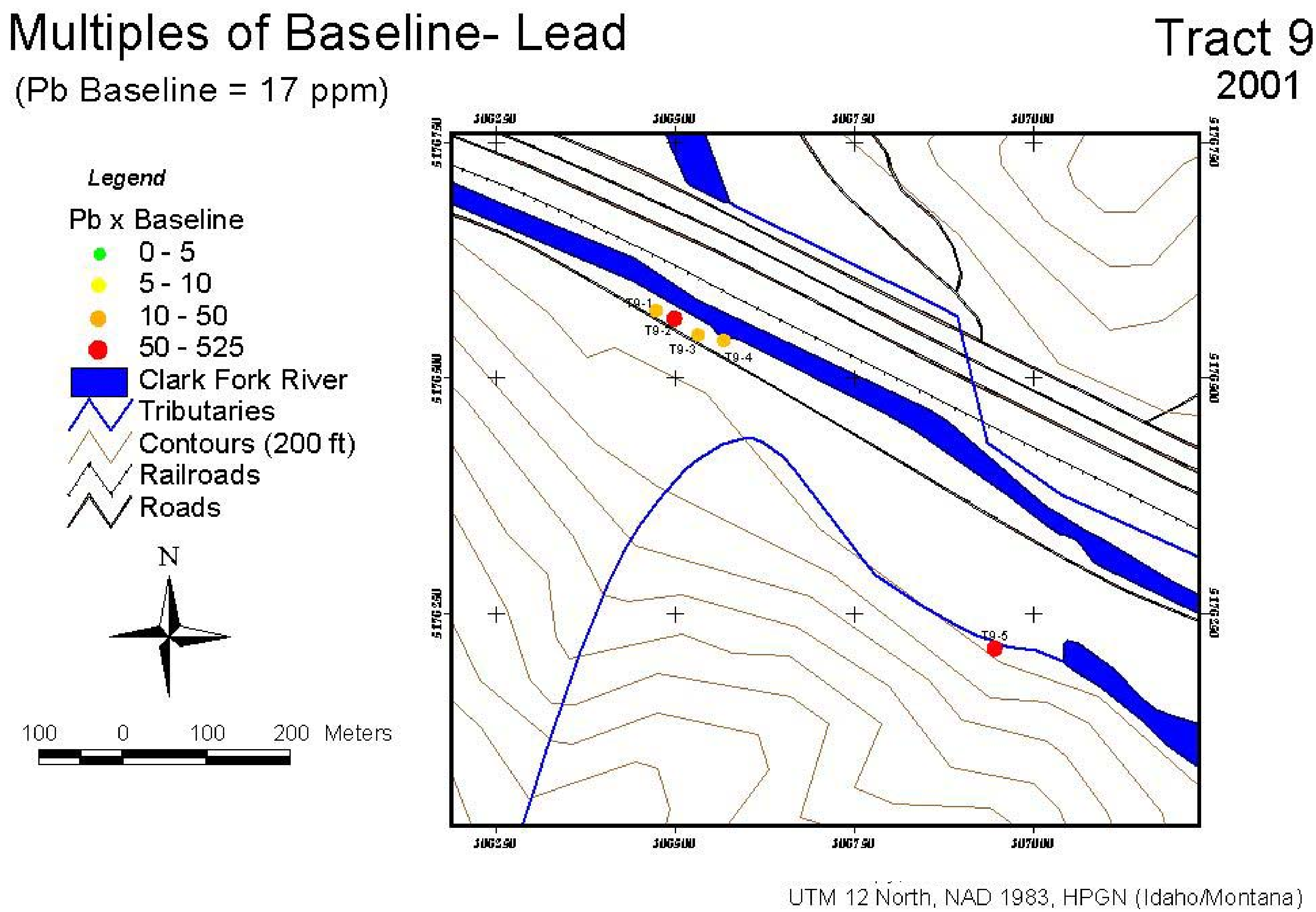


Figure III-44

Zinc Concentrations (ppm)

Tract 9
2001

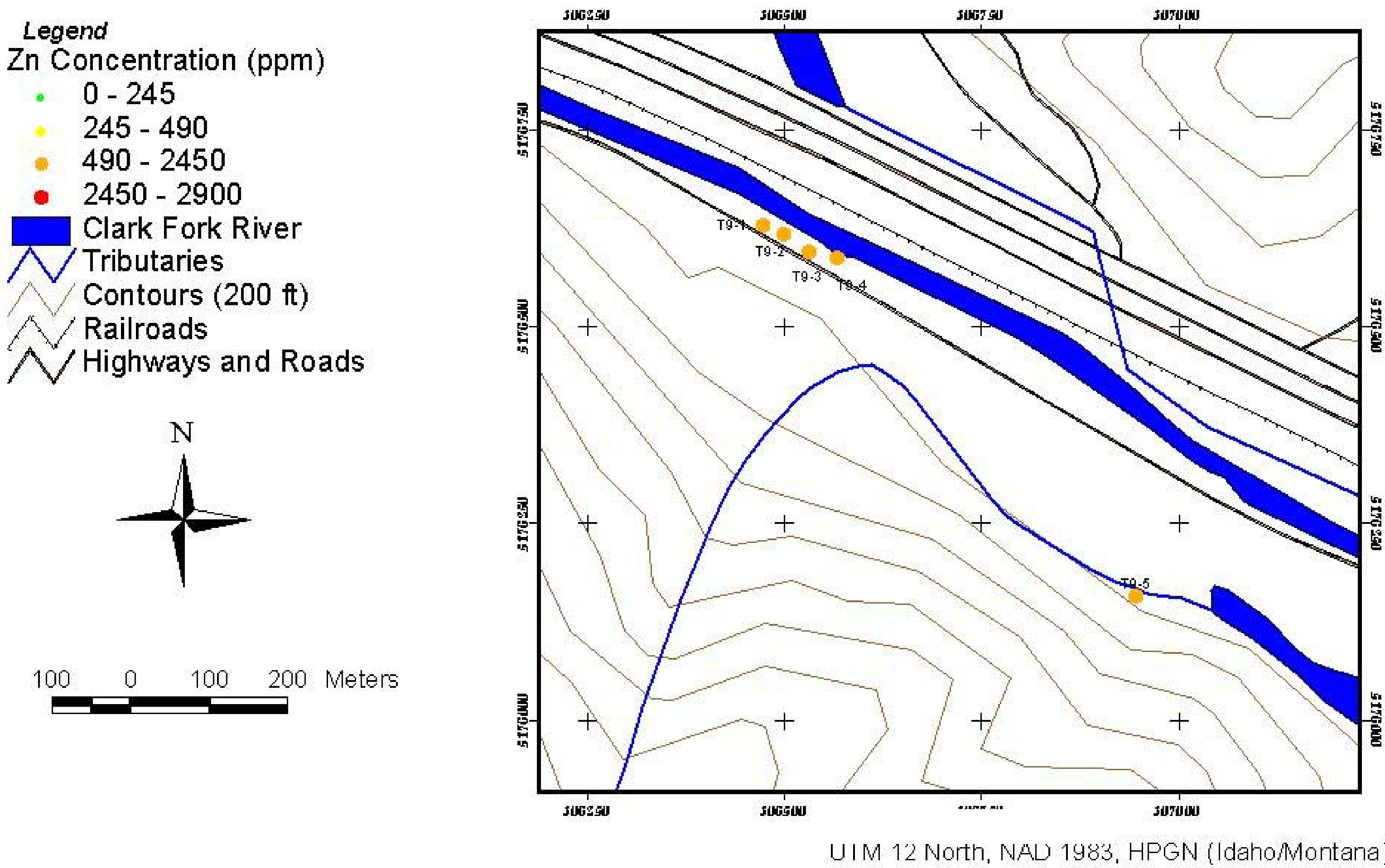


Figure III-45

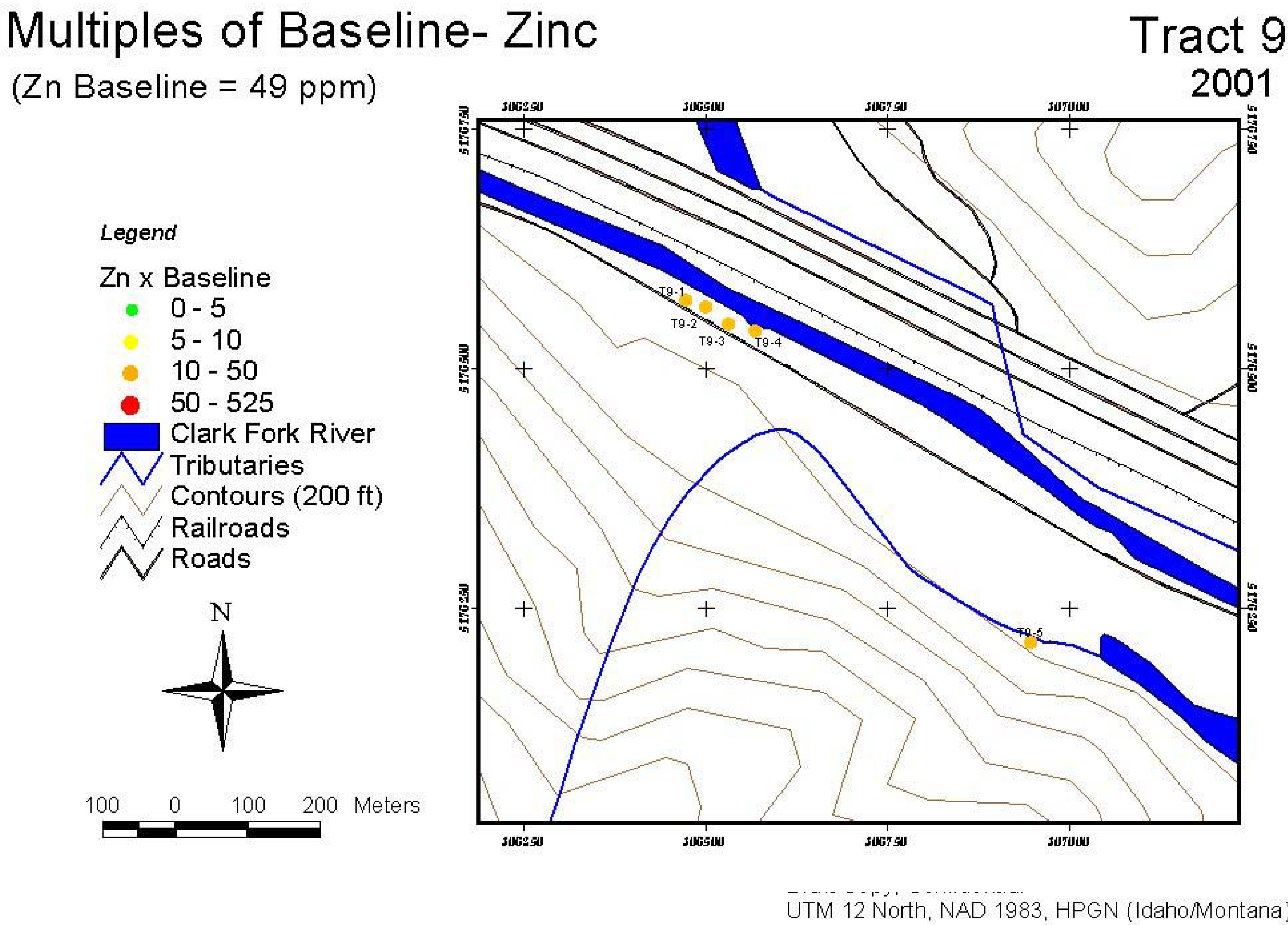


Figure III-46

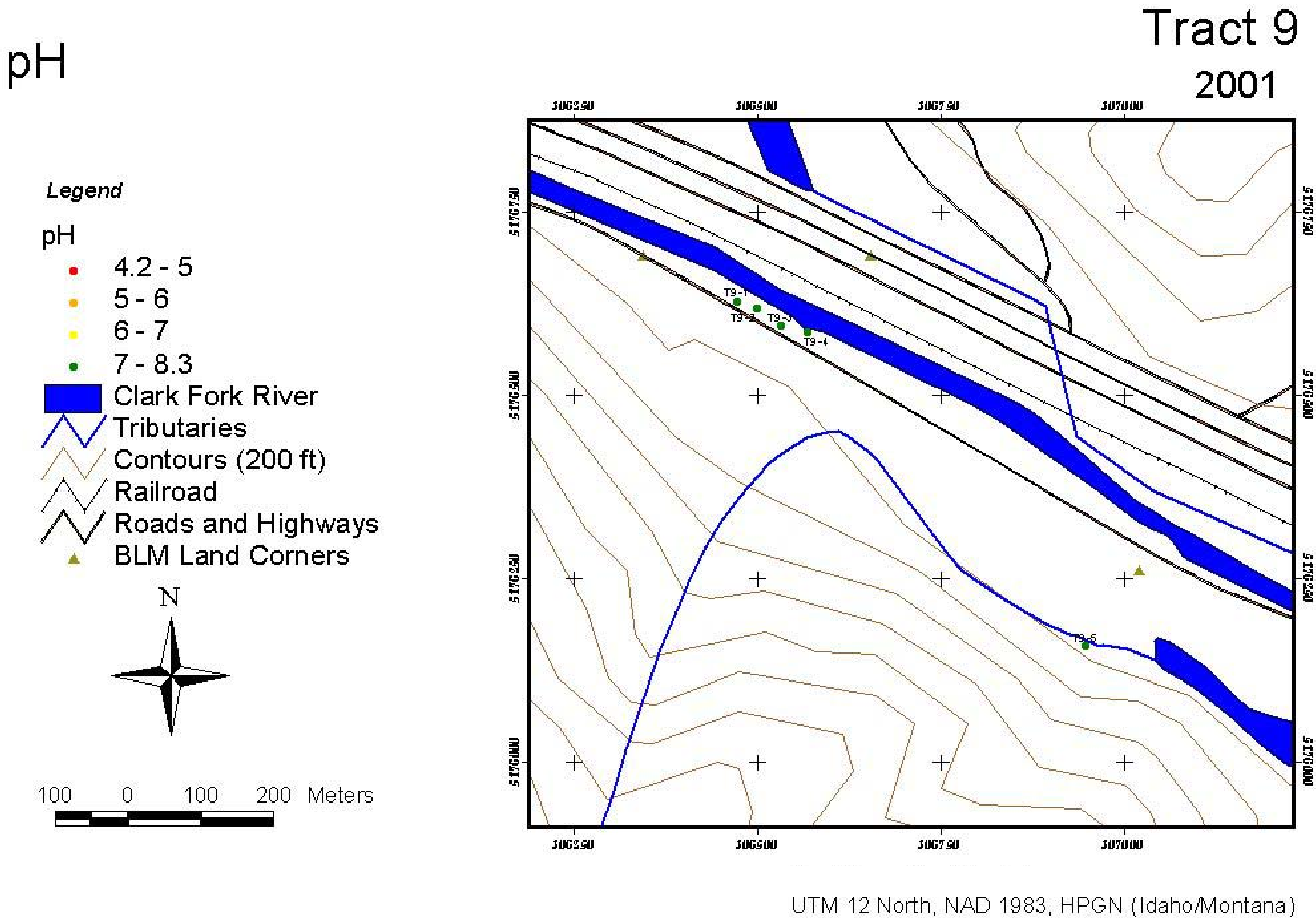


Figure III-47

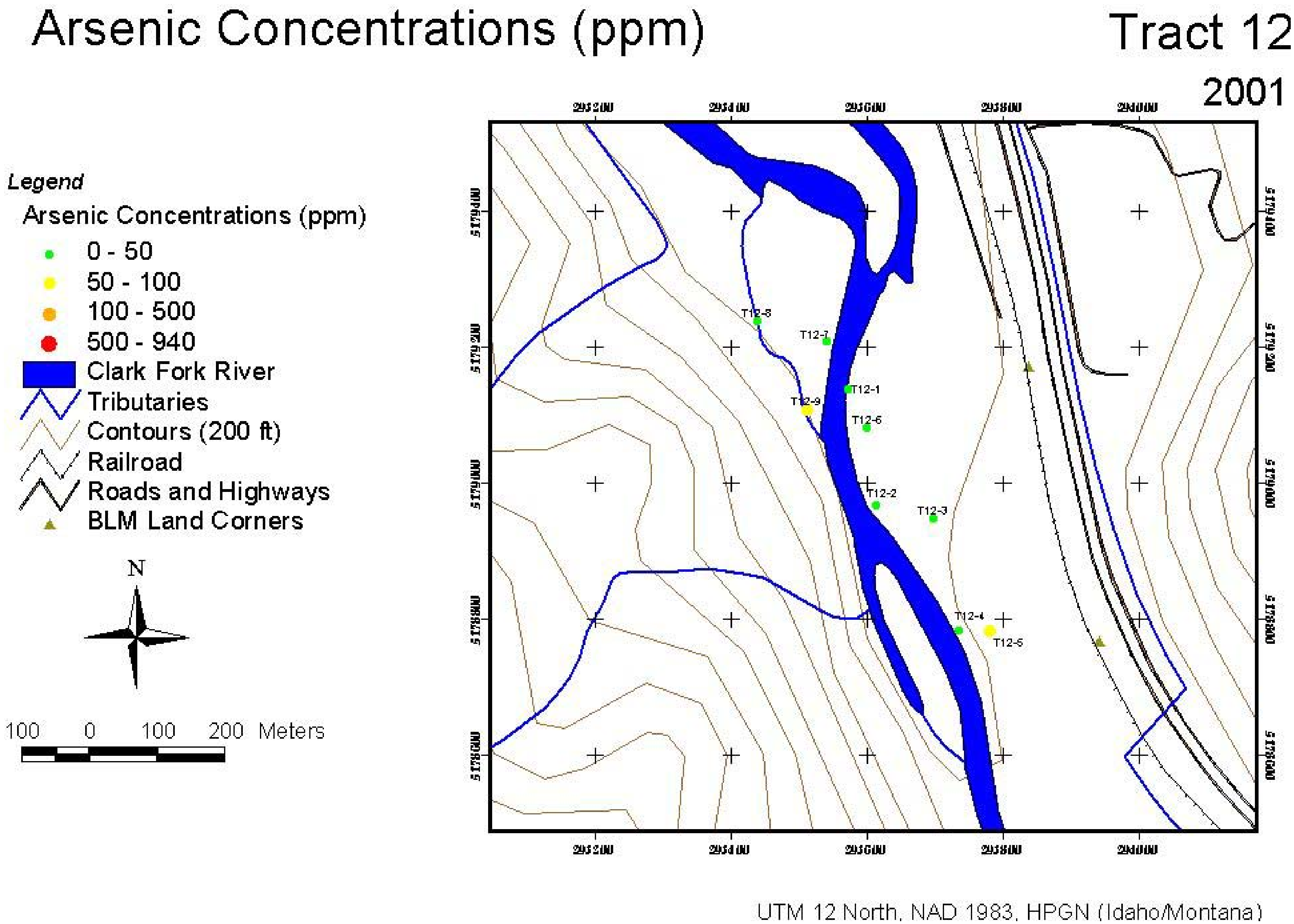


Figure III-48

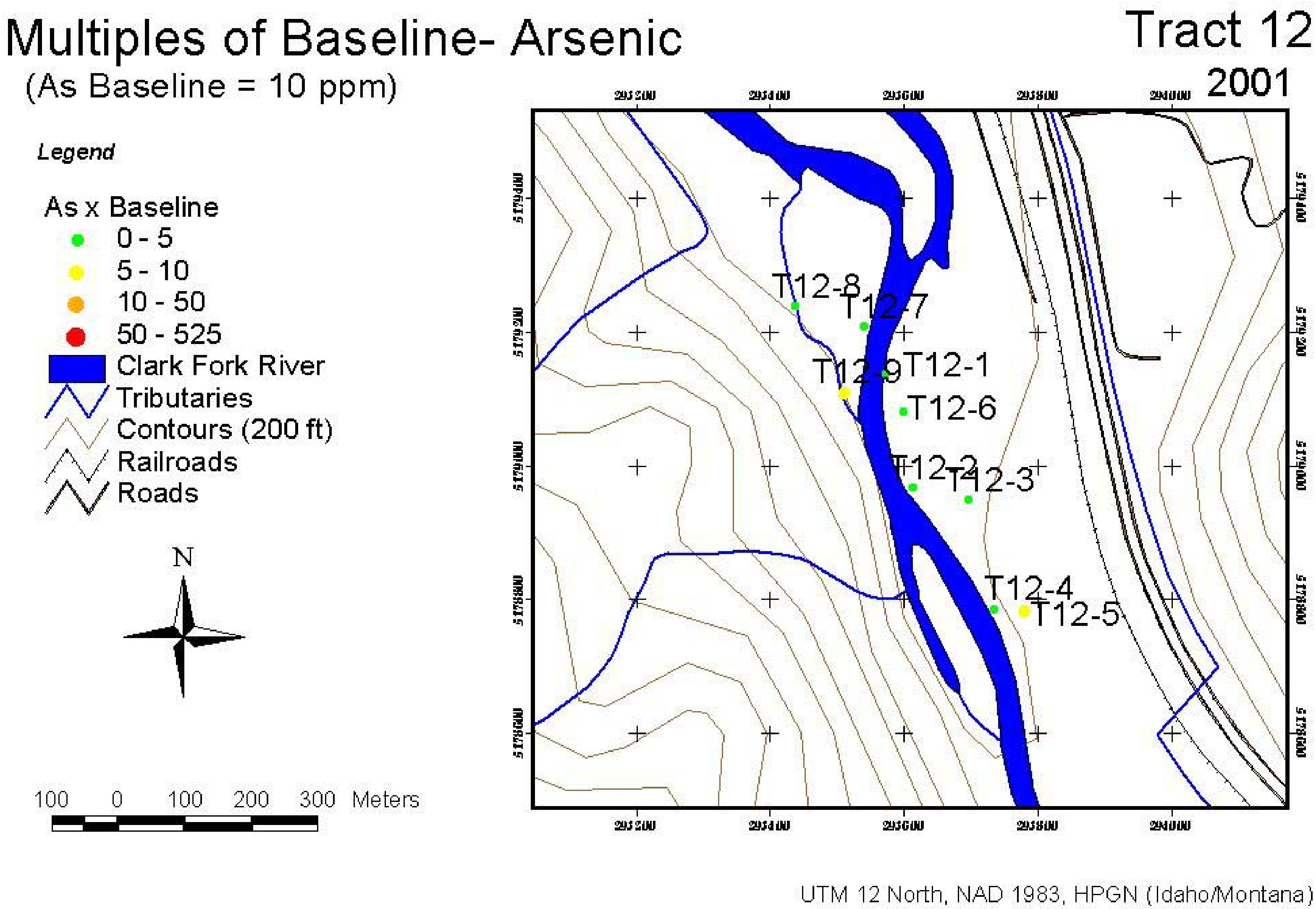


Figure III-49

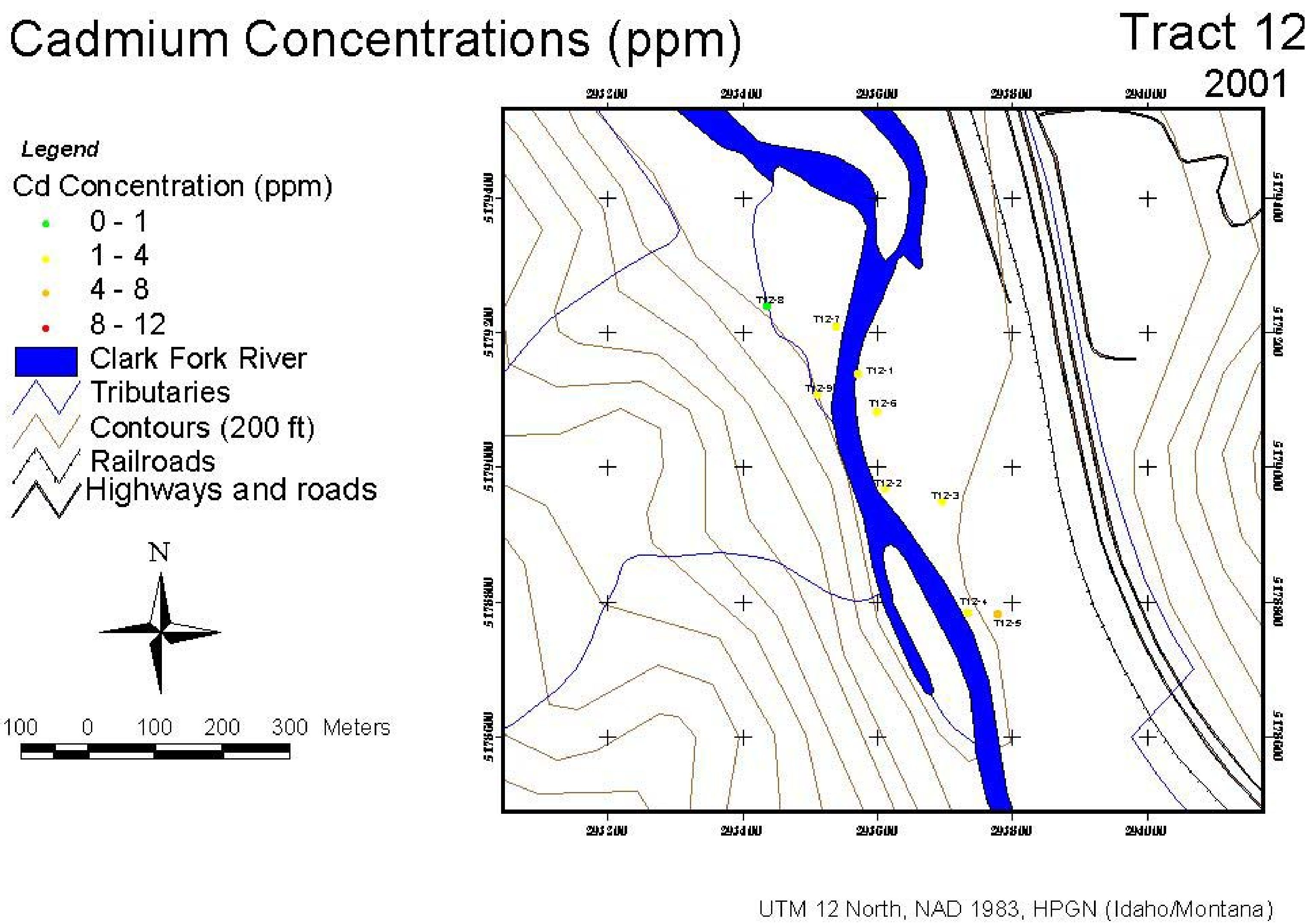


Figure III-50

Multiples of Baseline- Cadmium

(Cd Baseline = 1 ppm)

Tract 12

2001

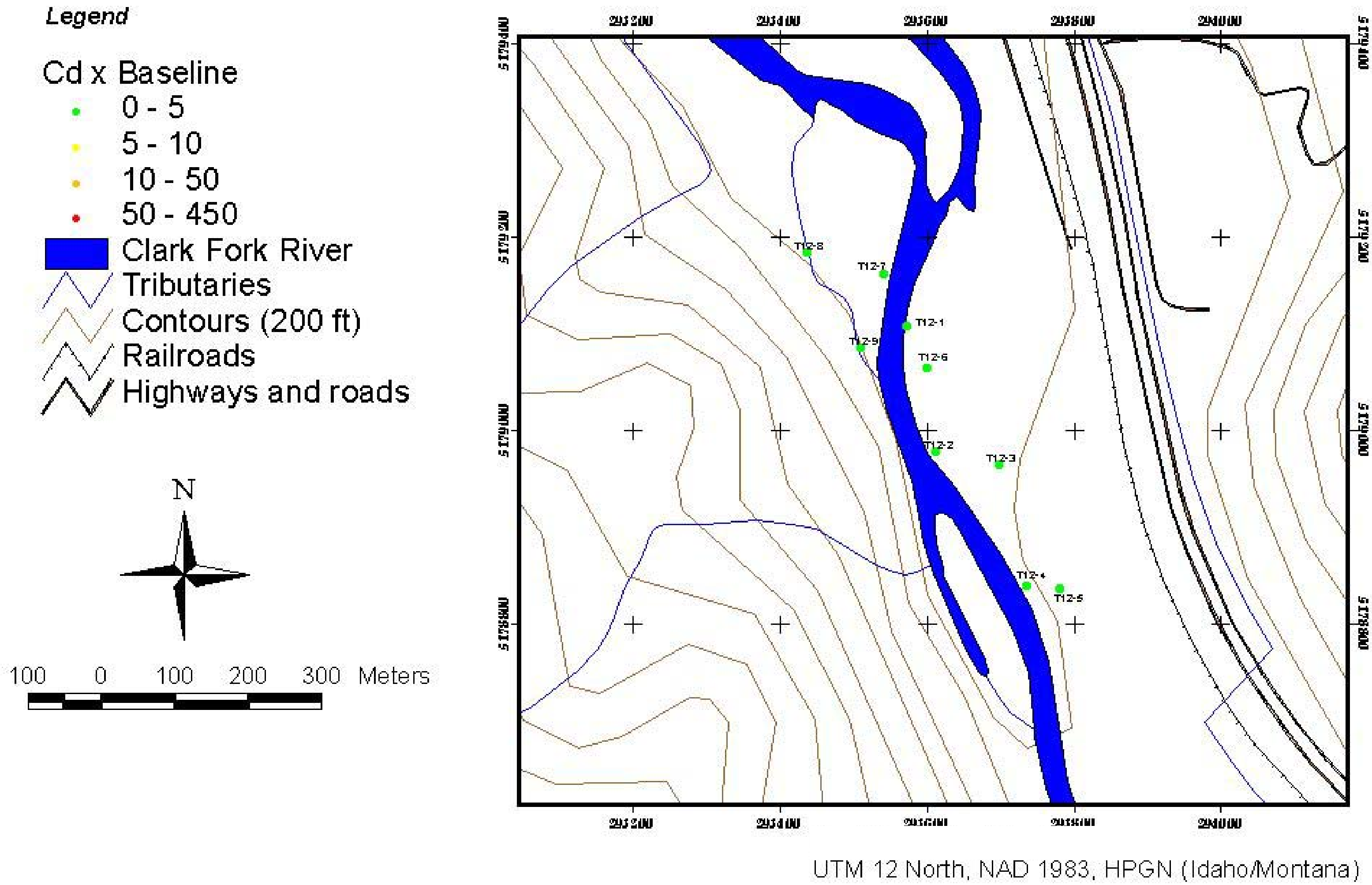


Figure III-51

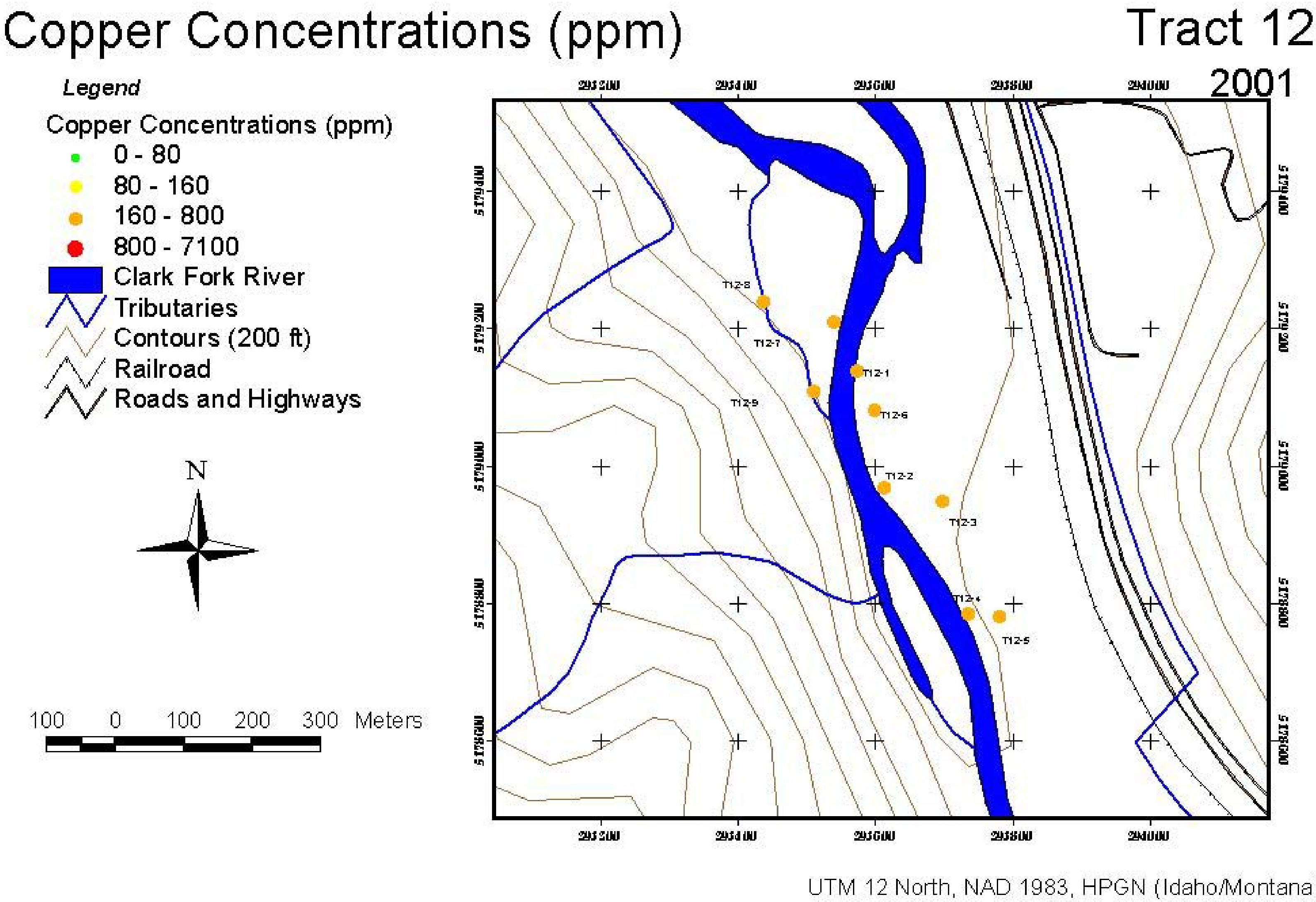


Figure III-52

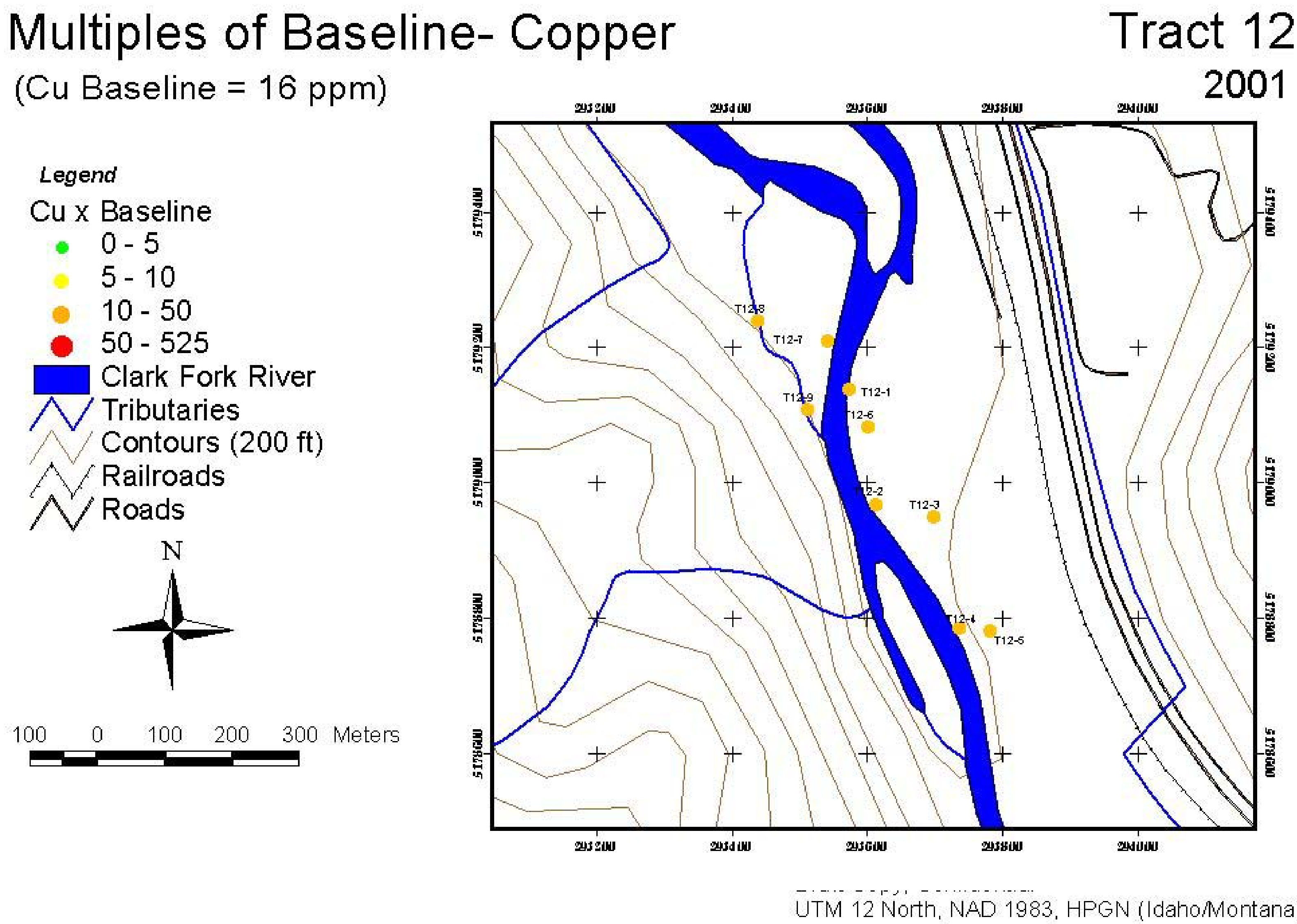


Figure III-53

Lead Concentrations (ppm)

Tract 12

2001

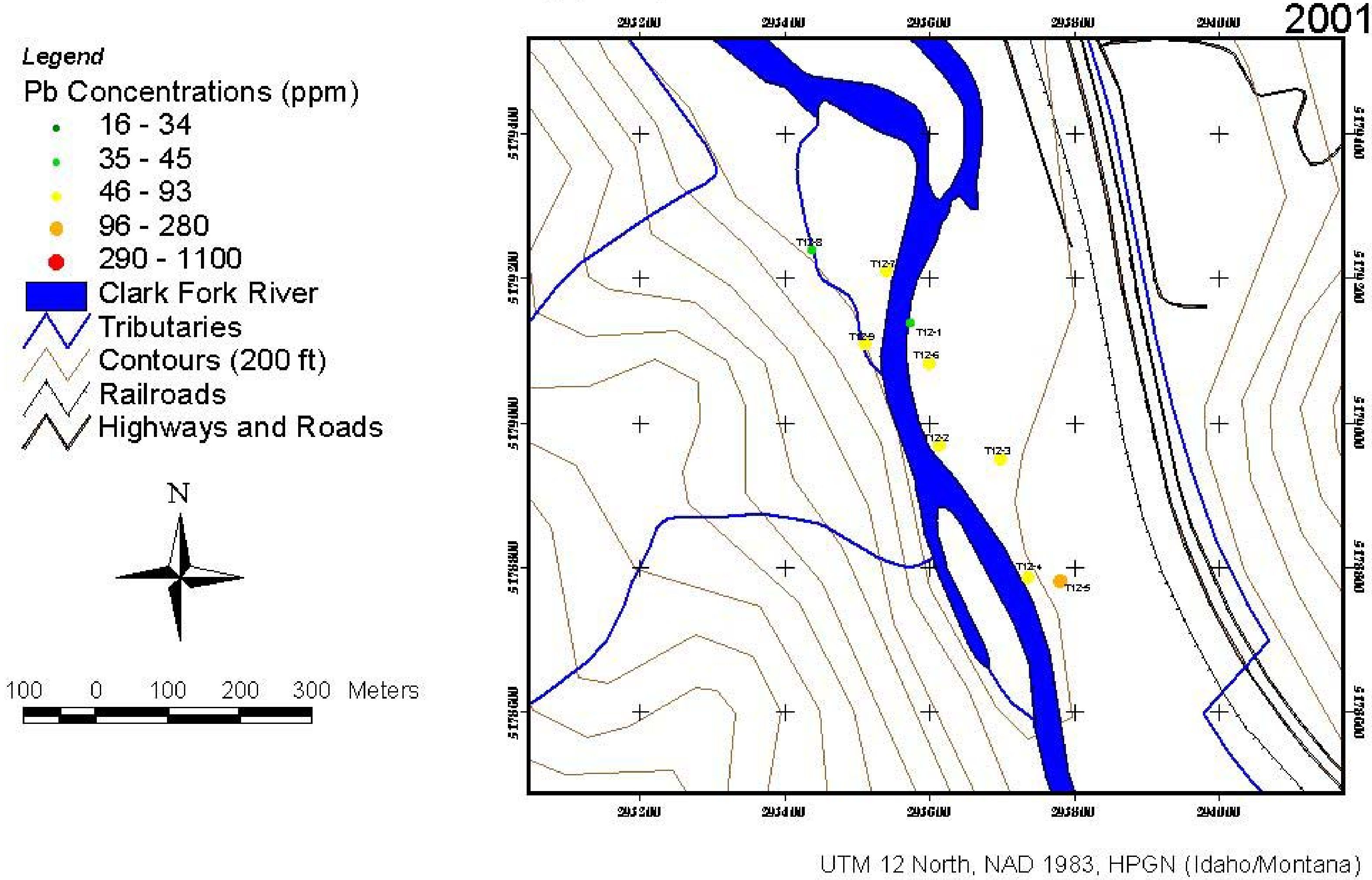


Figure III-54

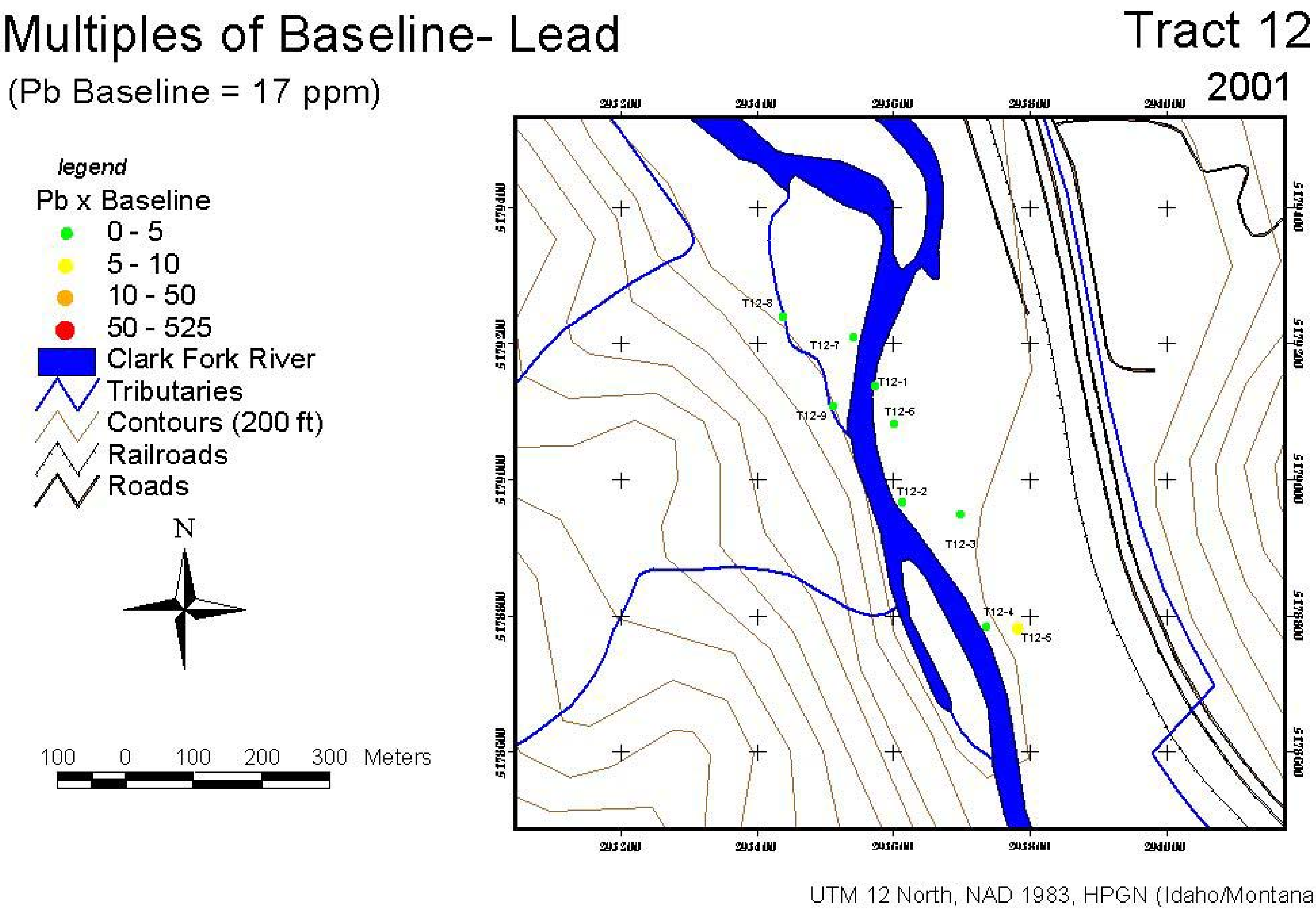


Figure III-55

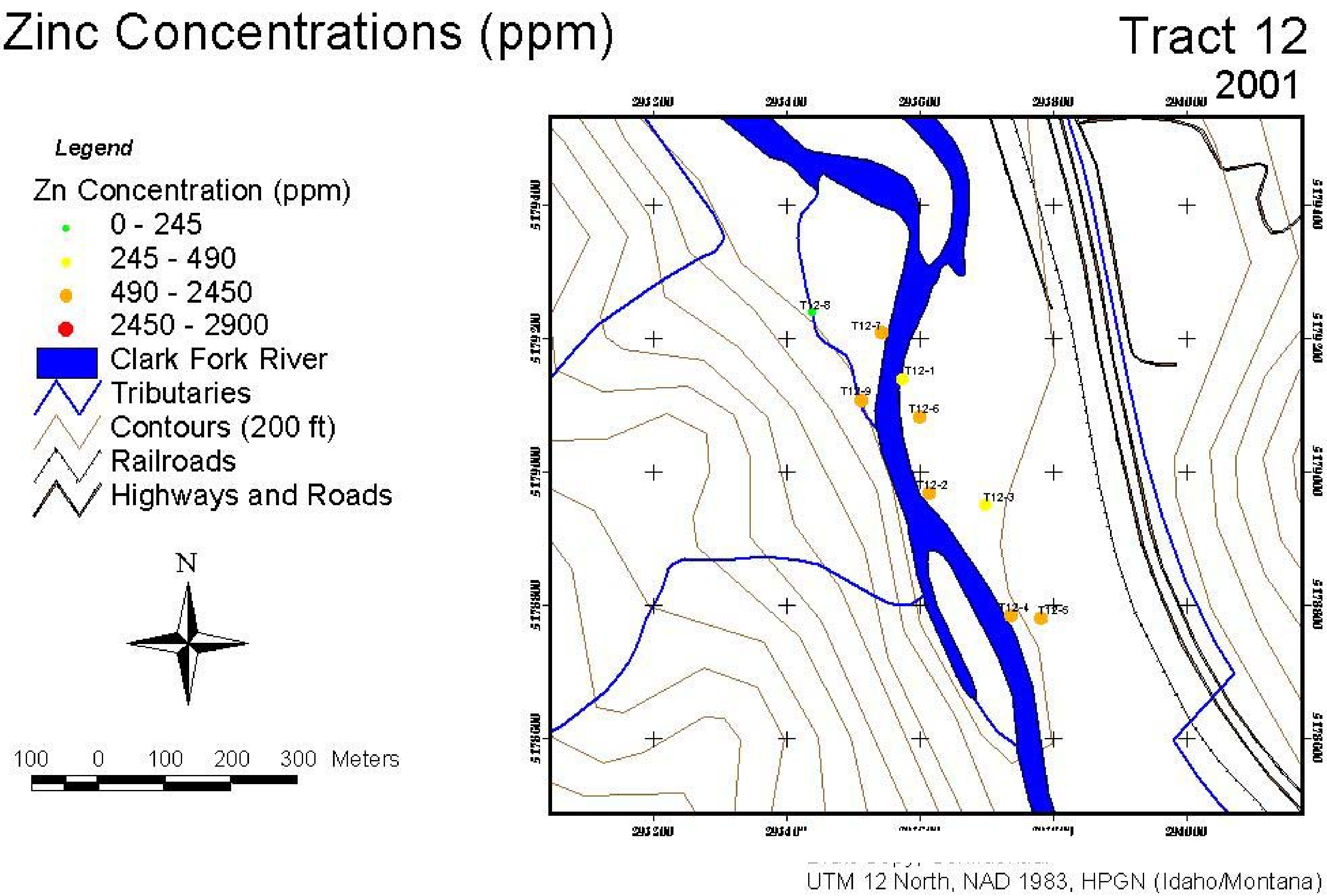


Figure III-56

Multiples of Baseline- Zinc

(Zn Baseline = 49 ppm)

Tract 12

2001

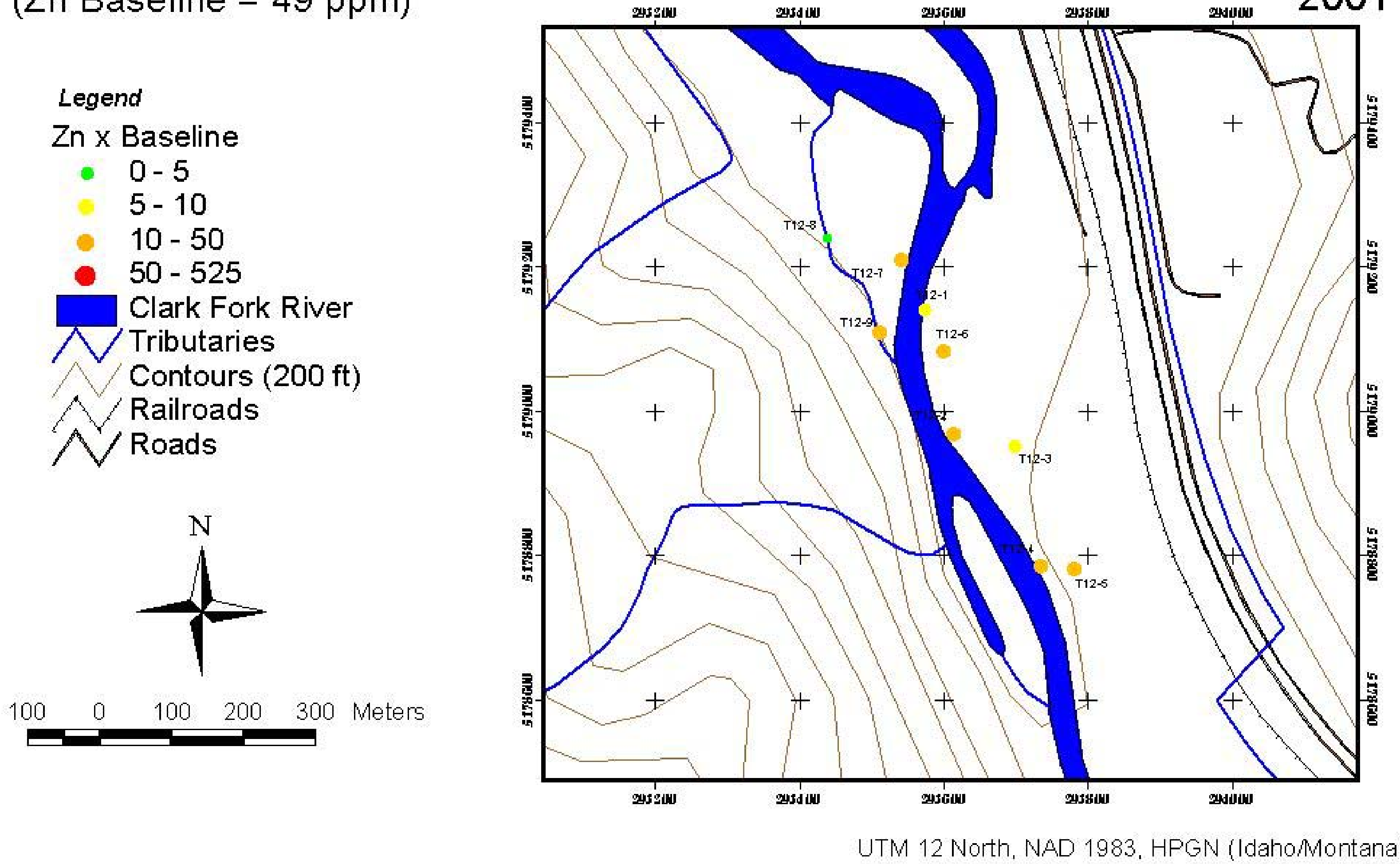


Figure III-57

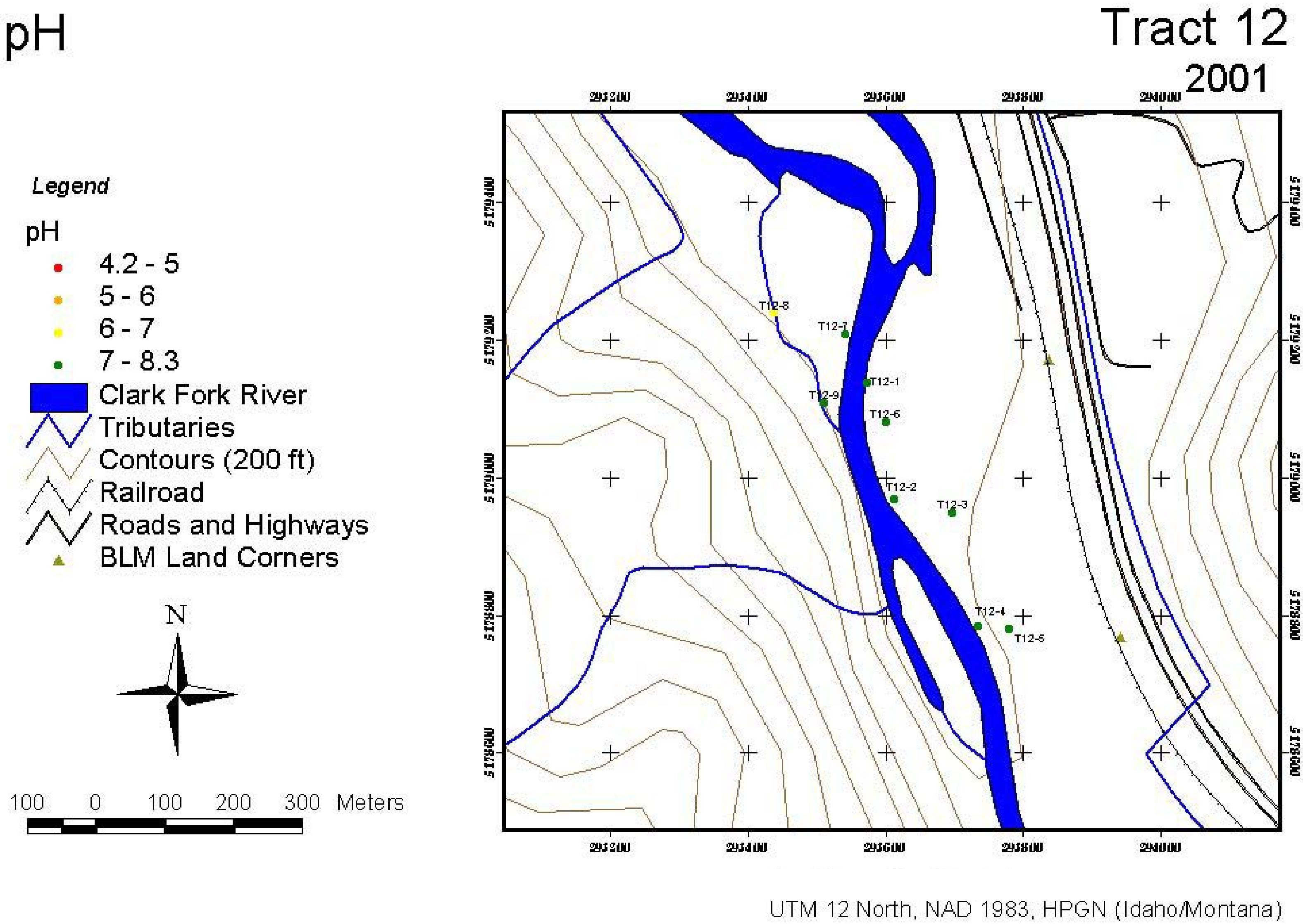


Figure III-58

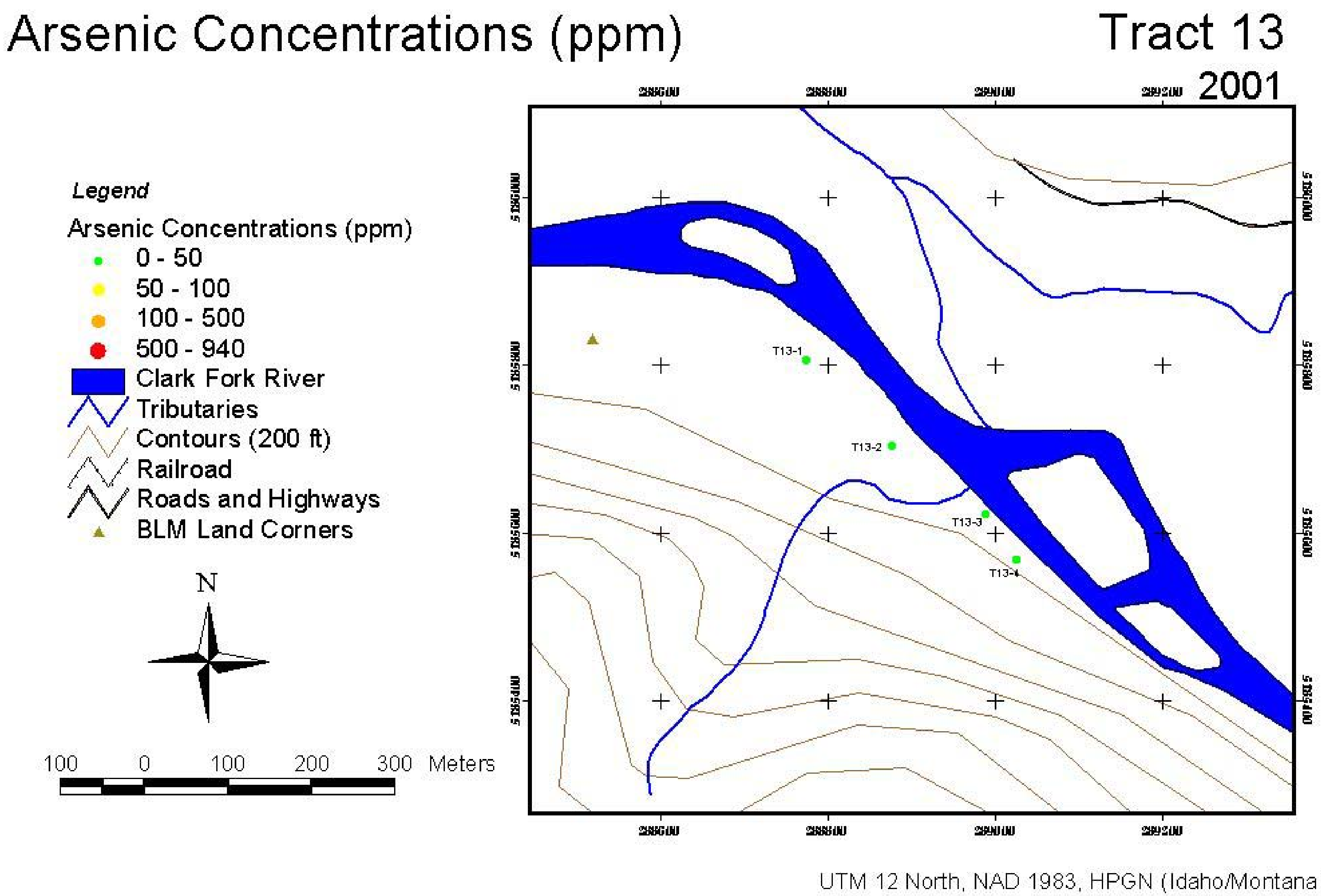


Figure III-59

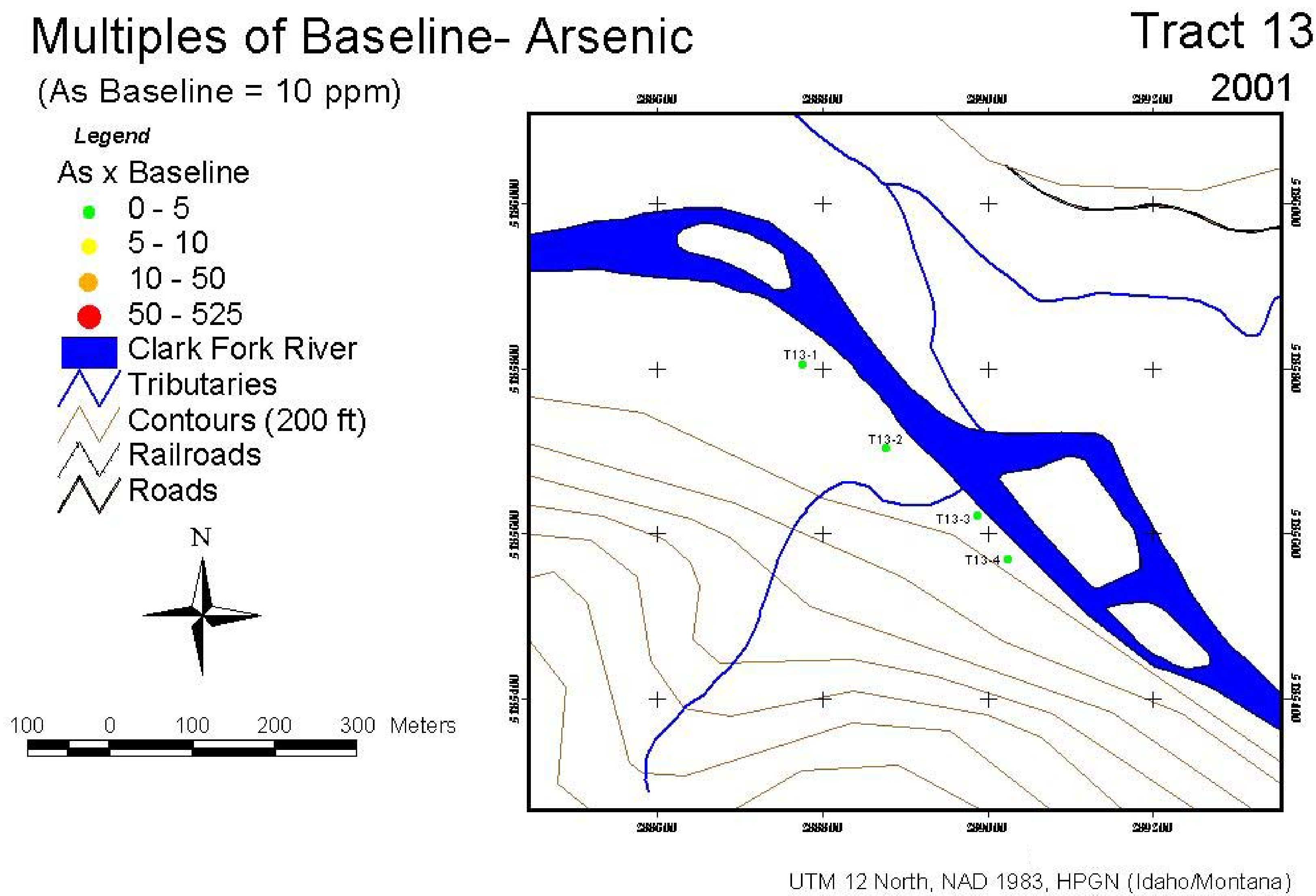


Figure III-60

Cadmium Concentrations (ppm) Tract 13

2001

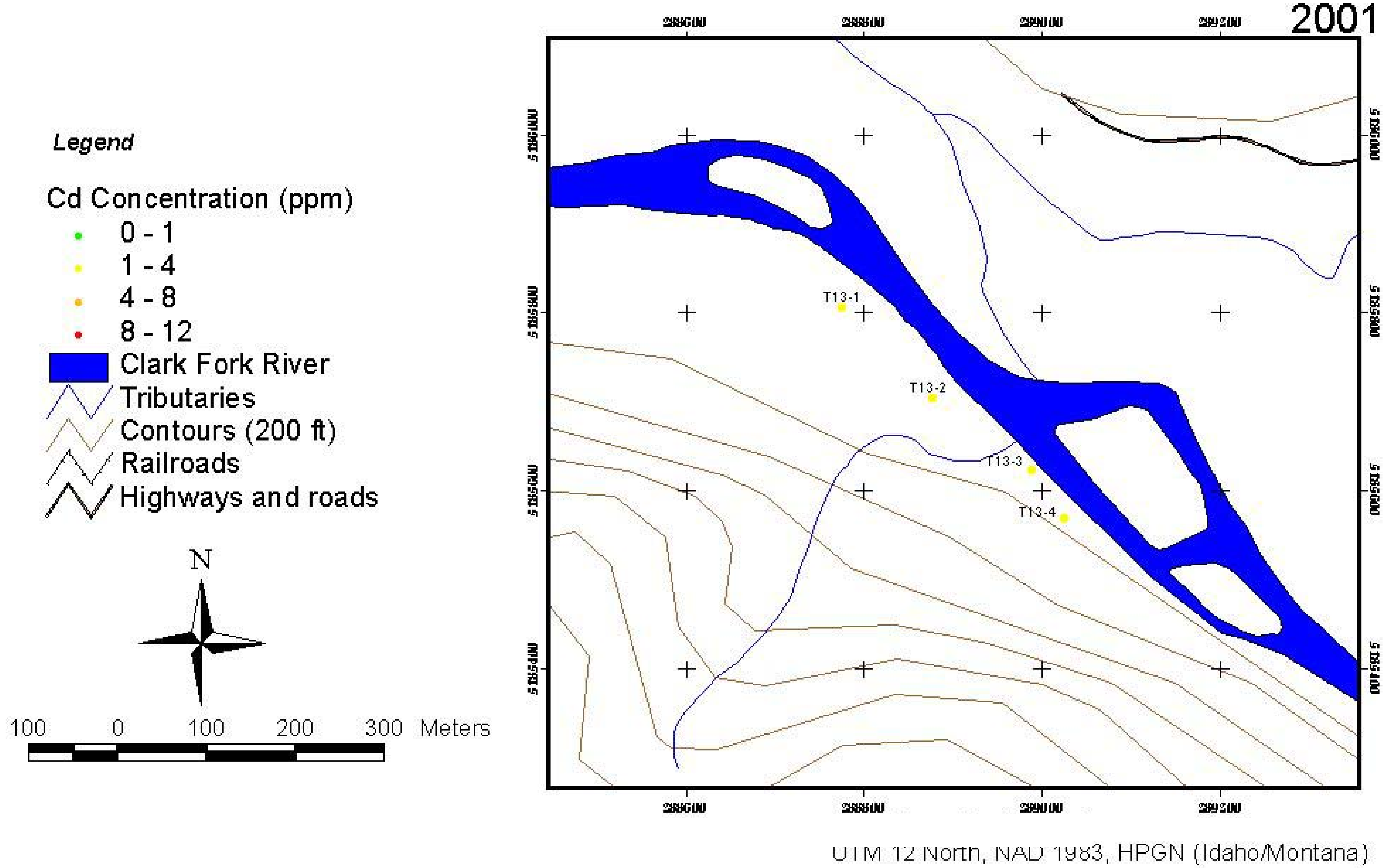


Figure III-61

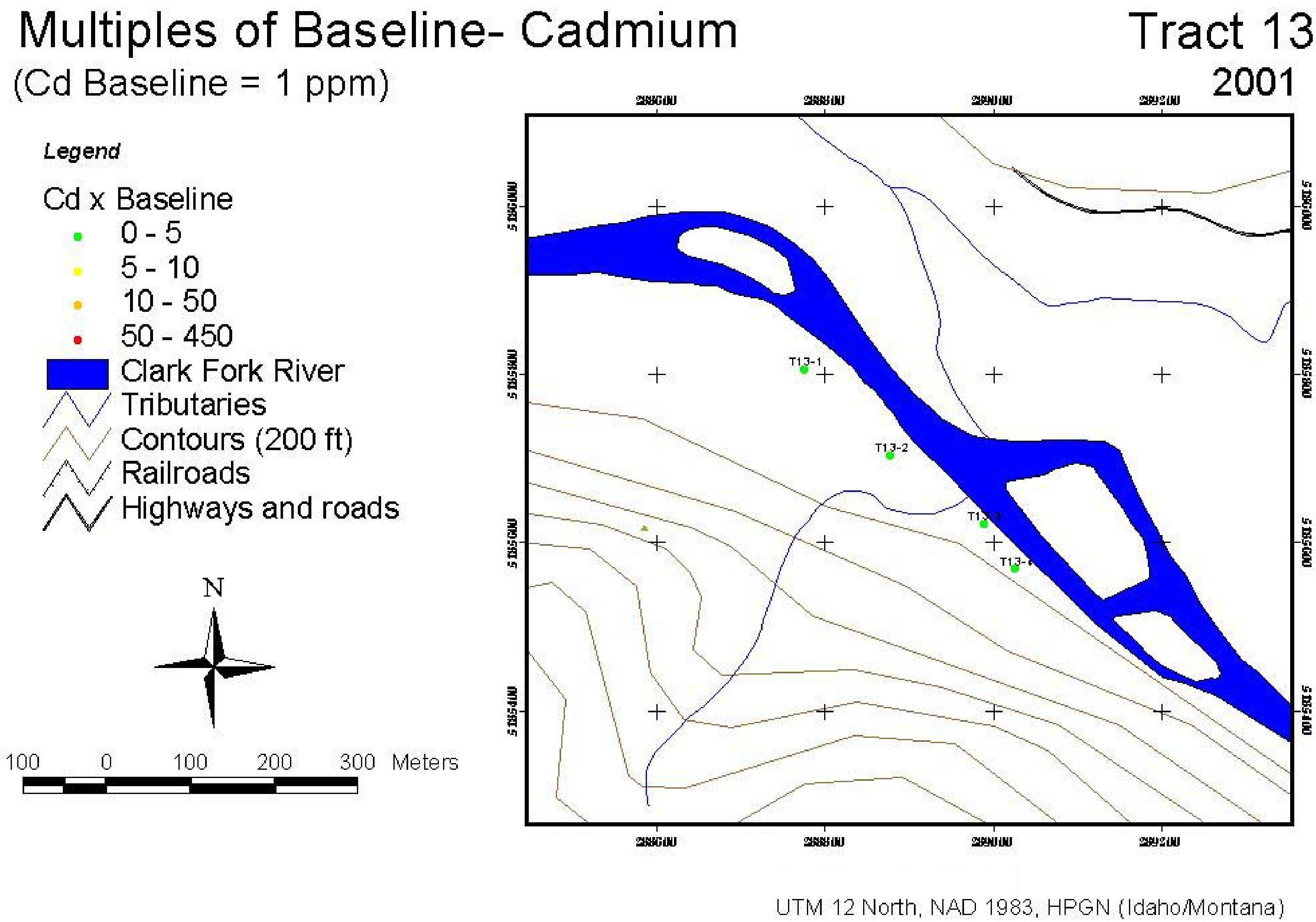


Figure III-62

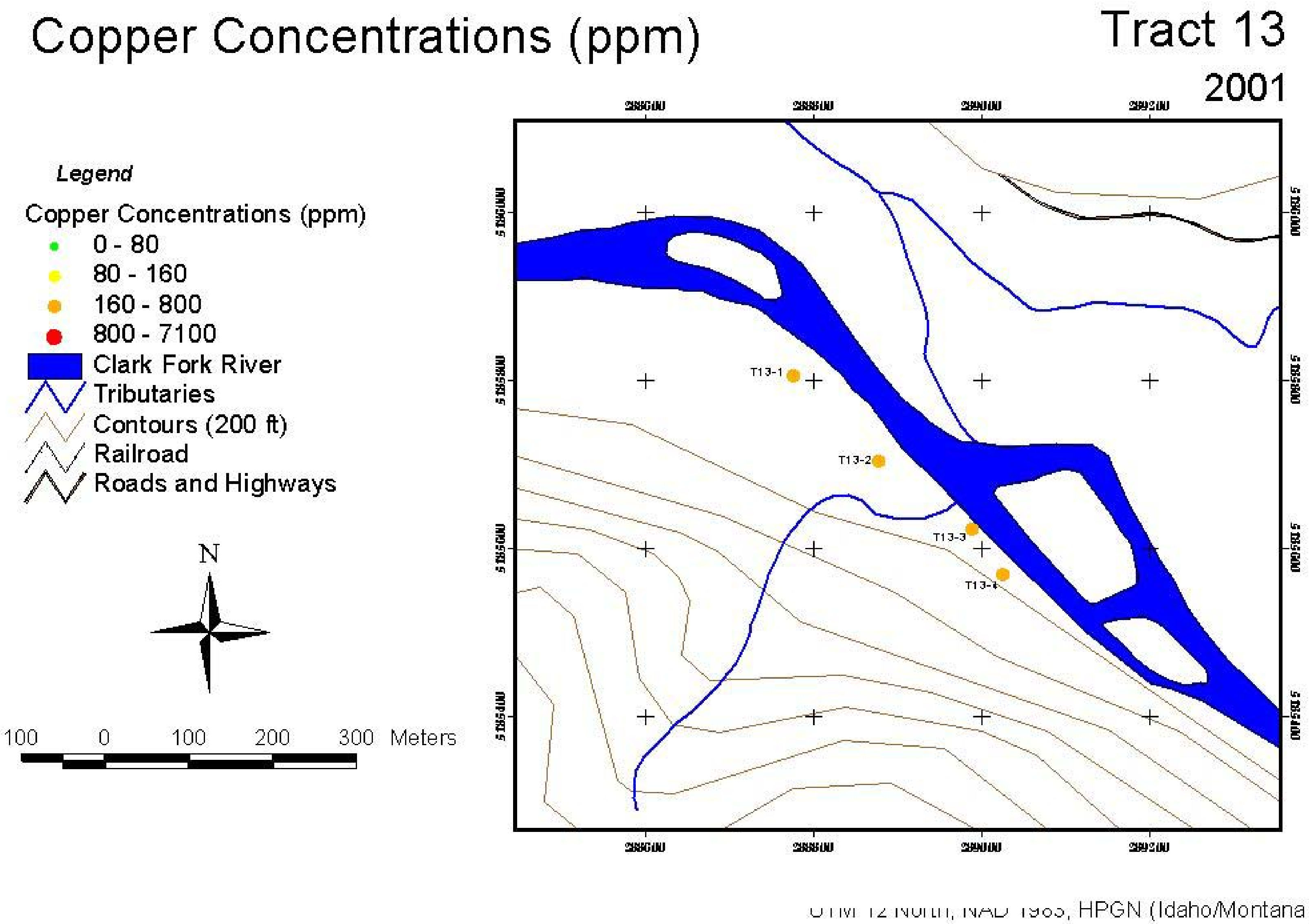


Figure III-63

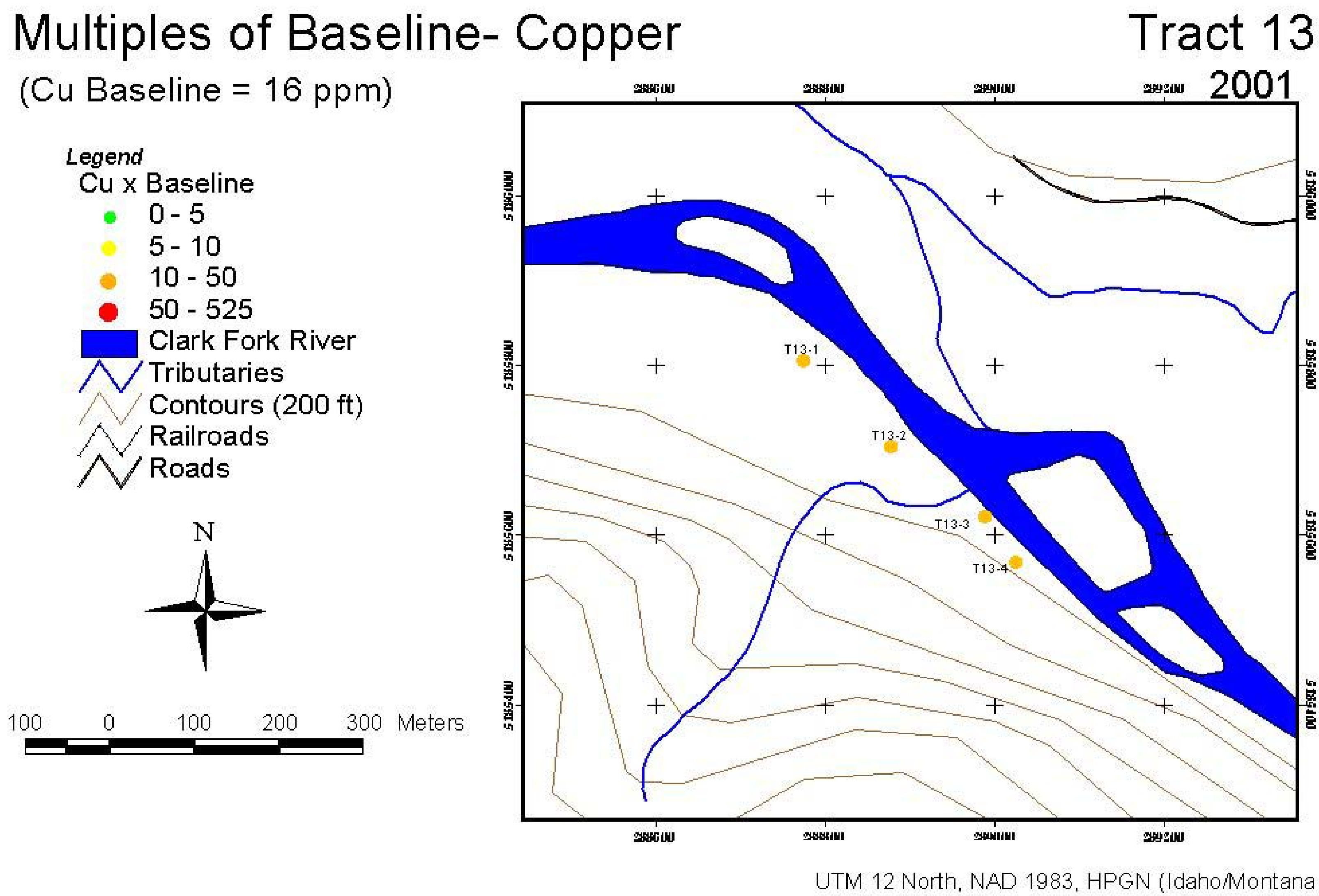


Figure III-64

Lead Concentrations (ppm)

Tract 13
2001

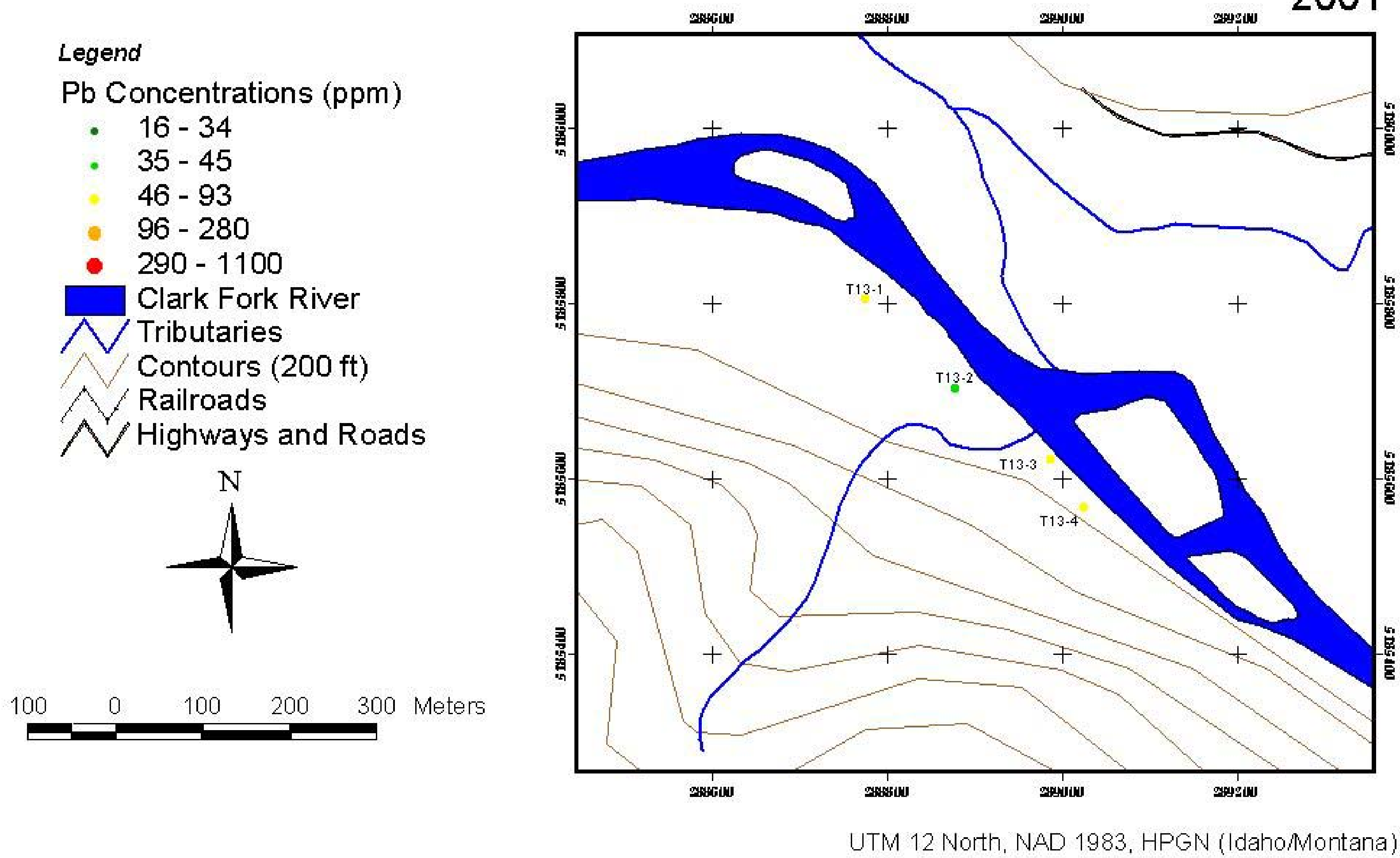


Figure III-65

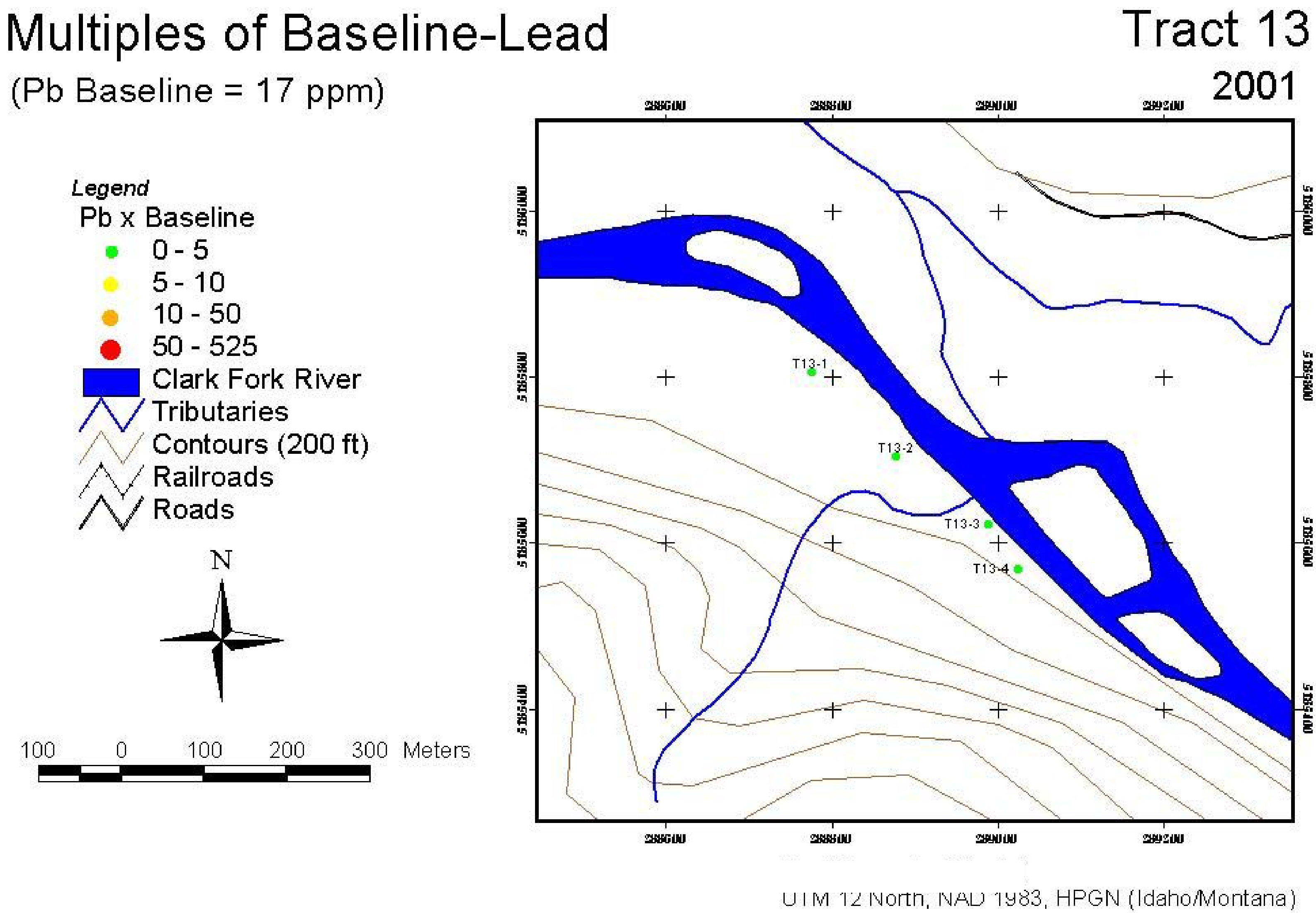


Figure III-66

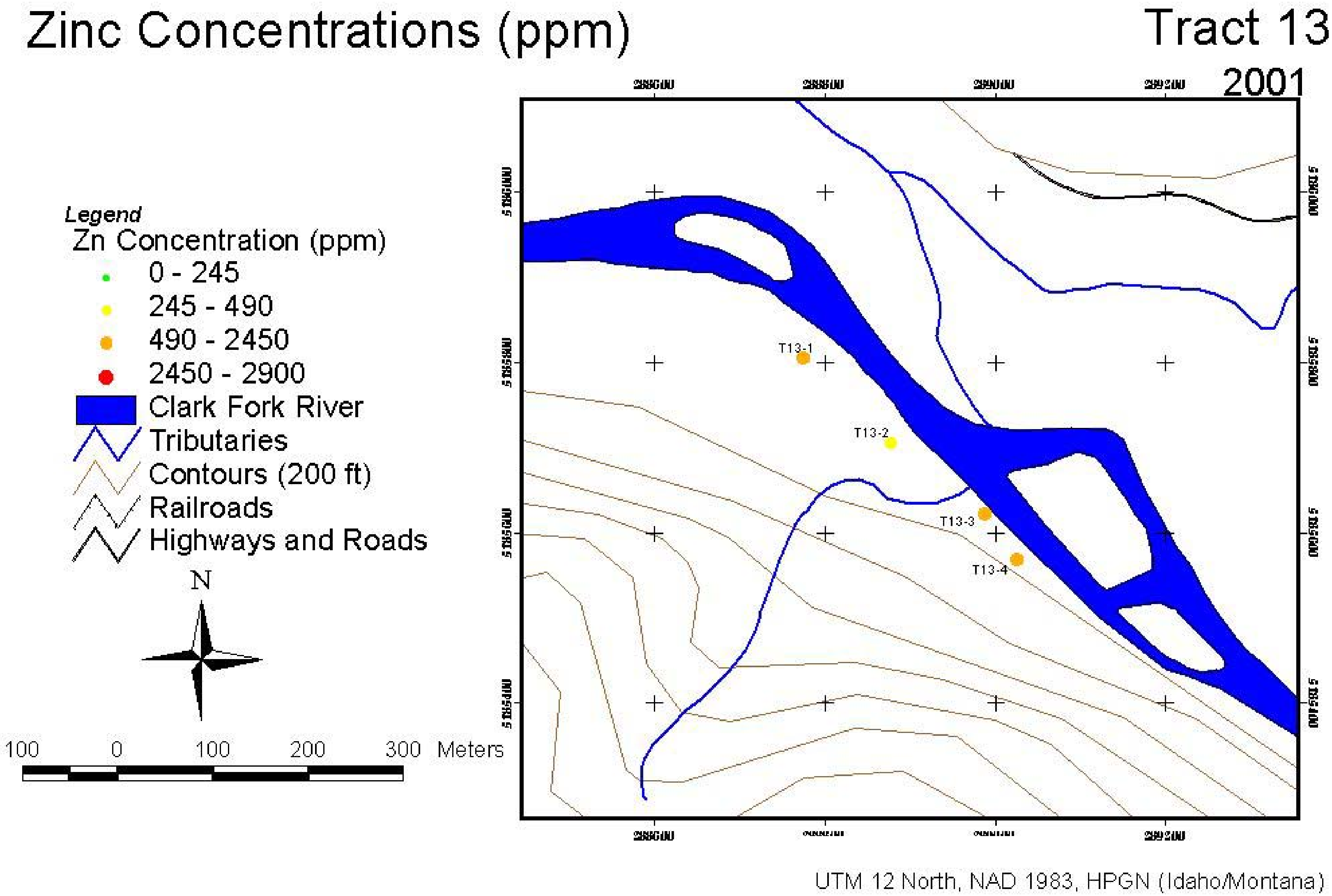


Figure III-67

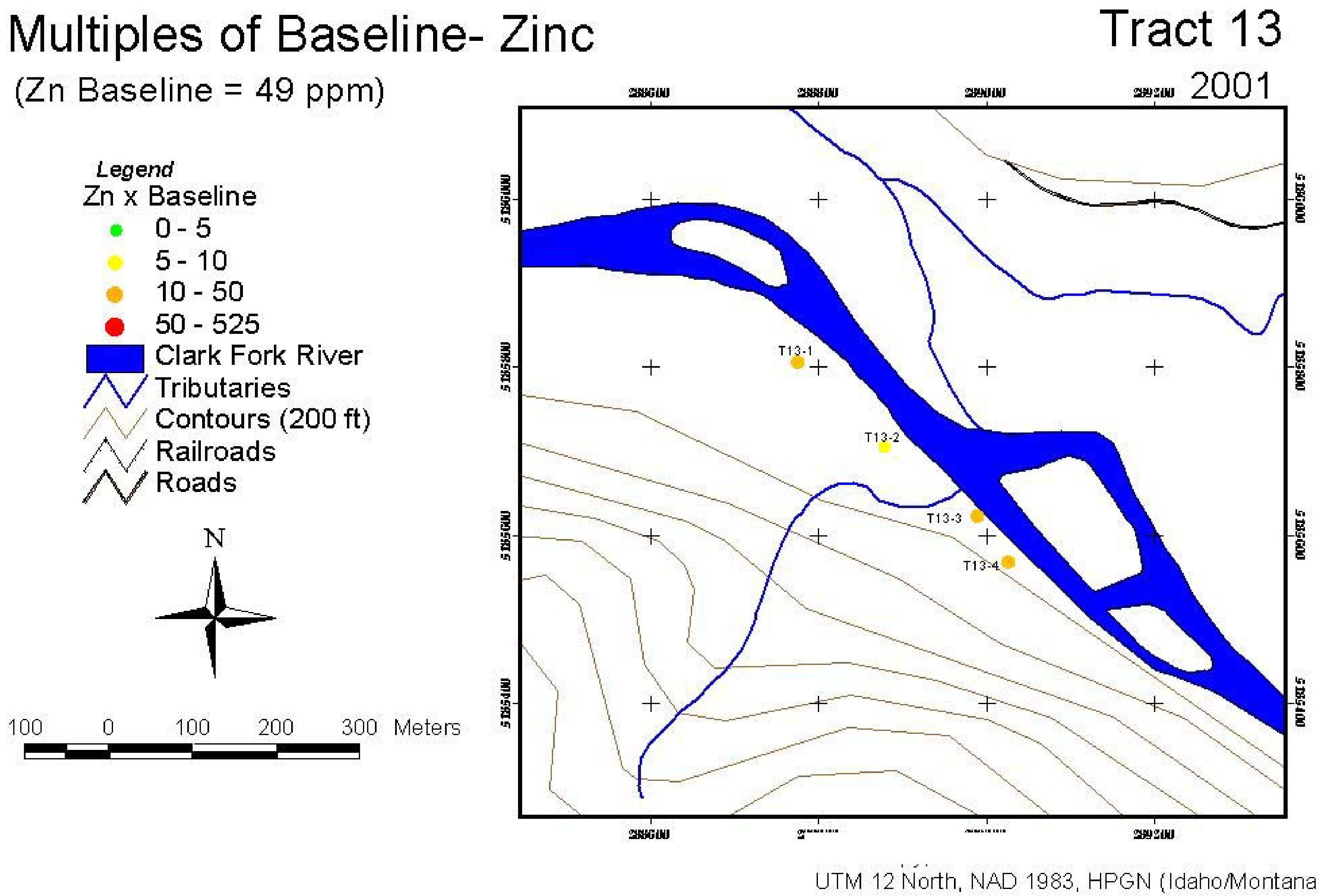


Figure III-68

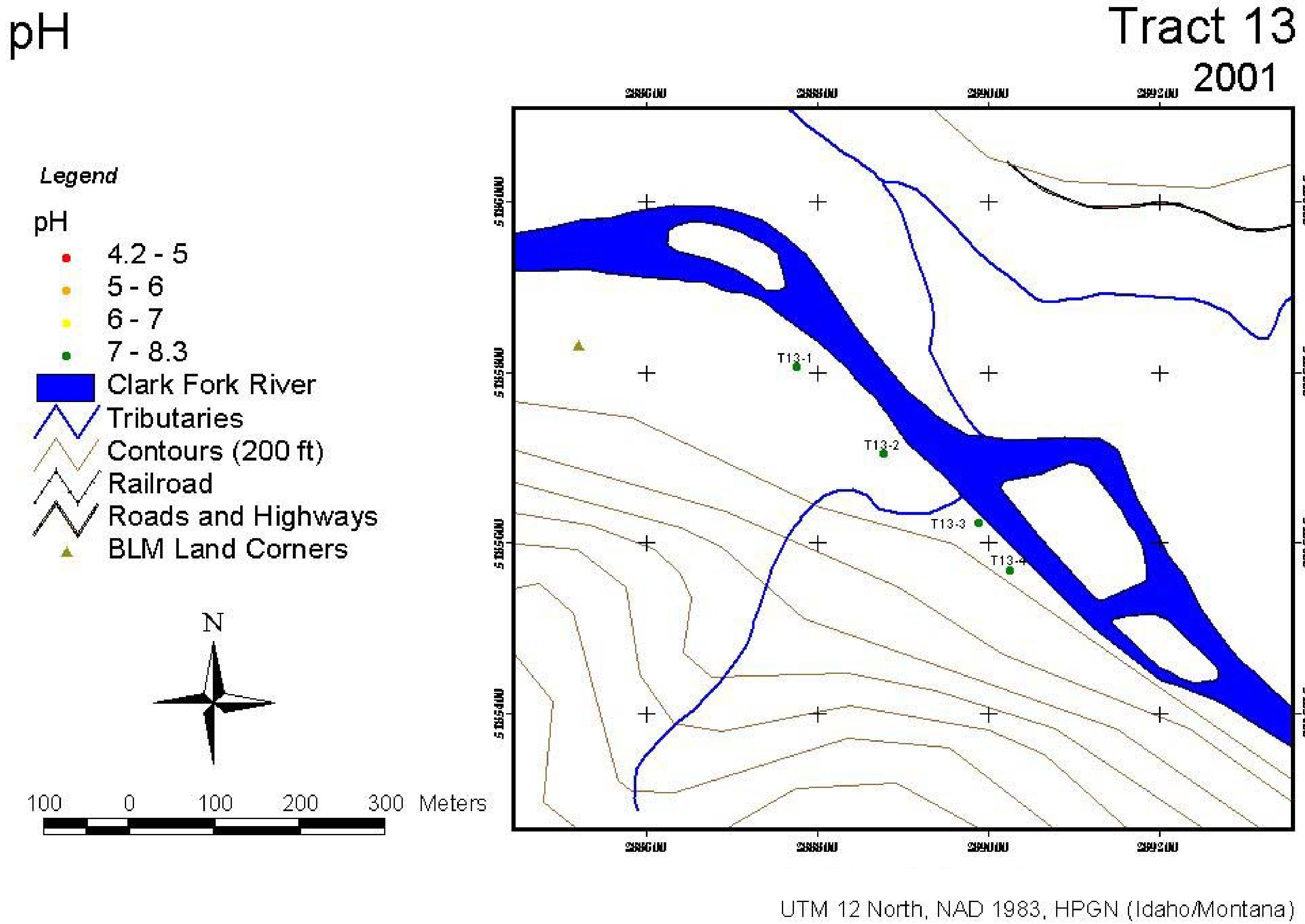


Figure III-69

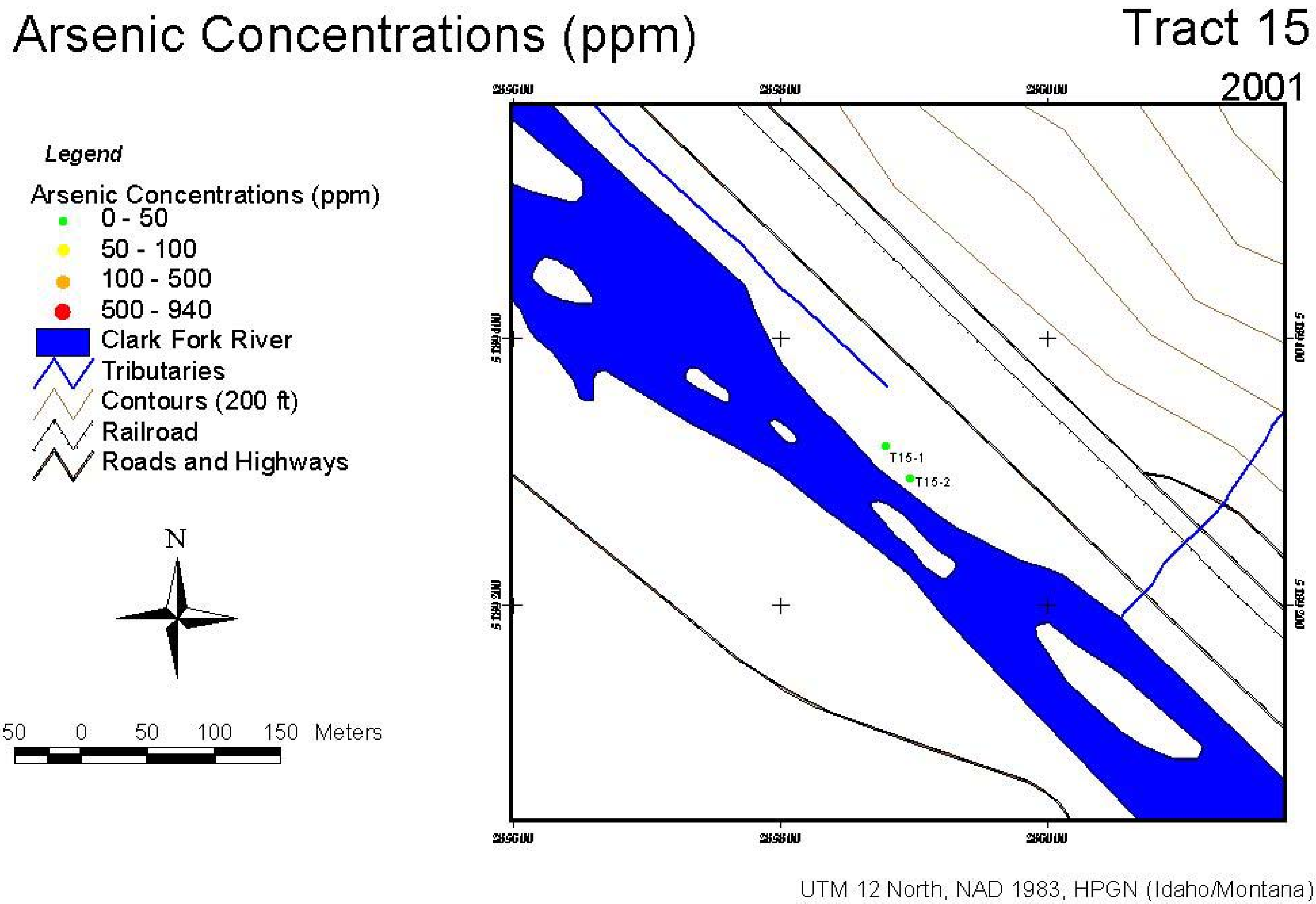


Figure III-70

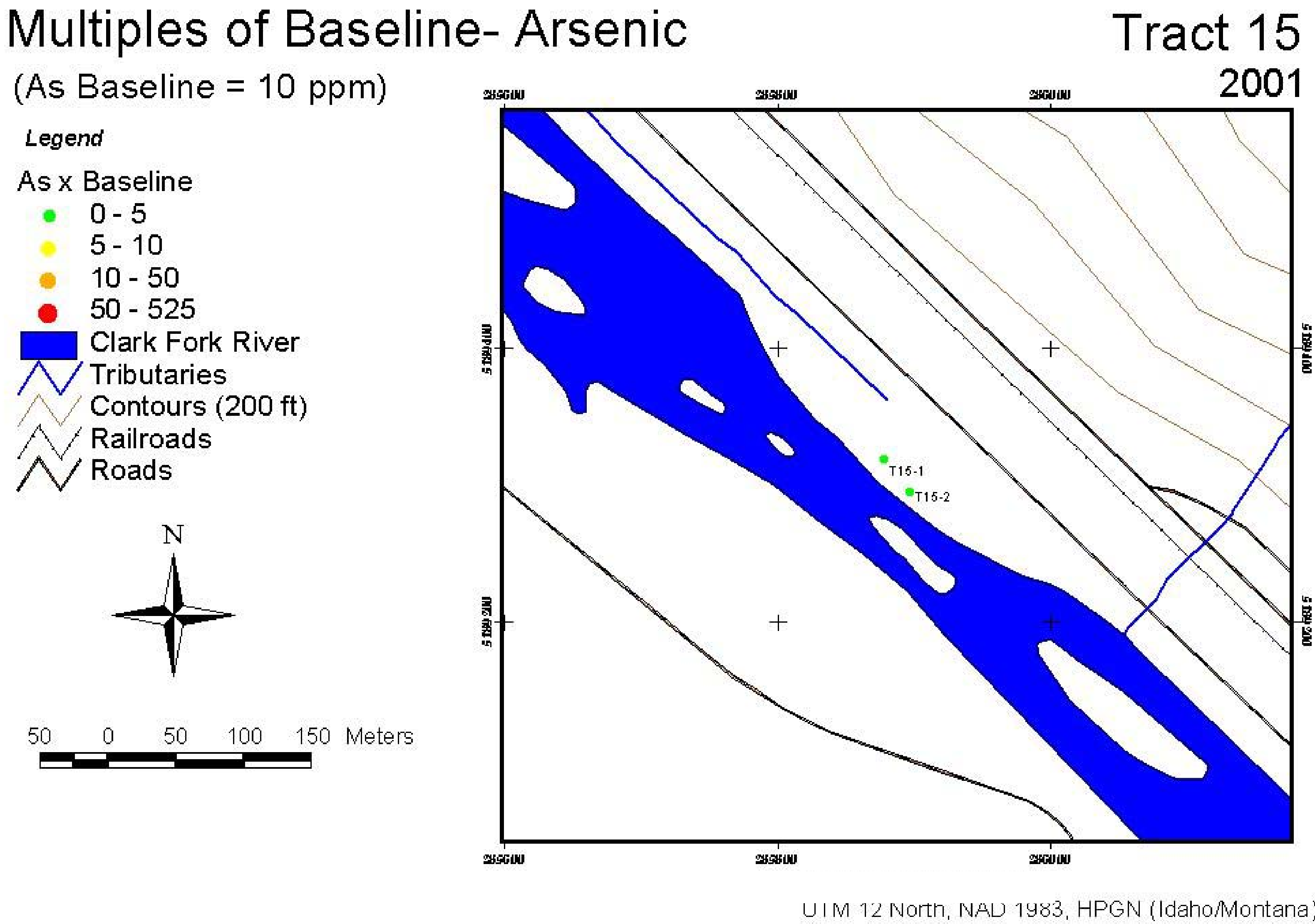


Figure III-71

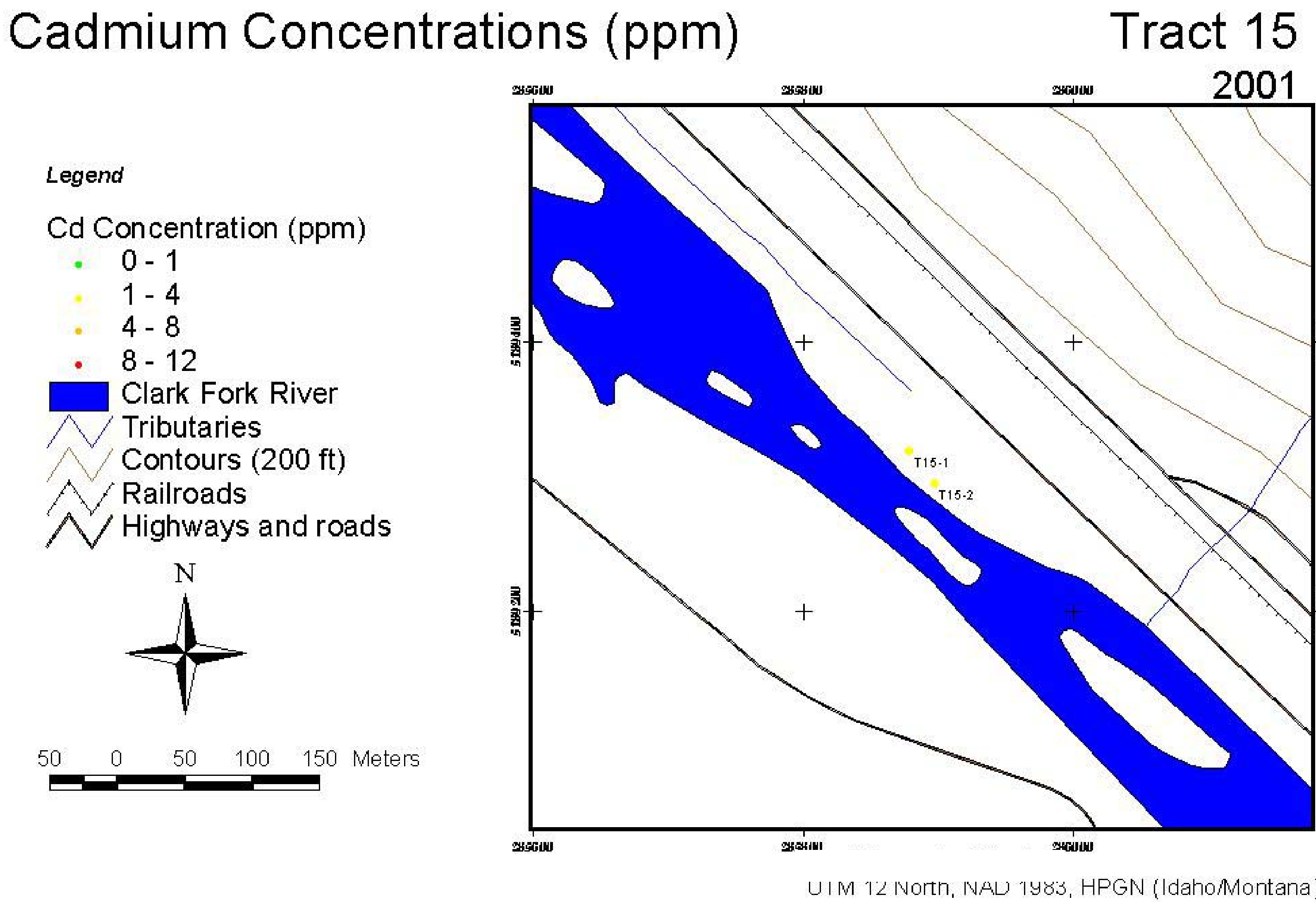


Figure III-72

Multiples of Baseline- Cadmium

(Cd Baseline = 1 ppm)

Tract 15

2001

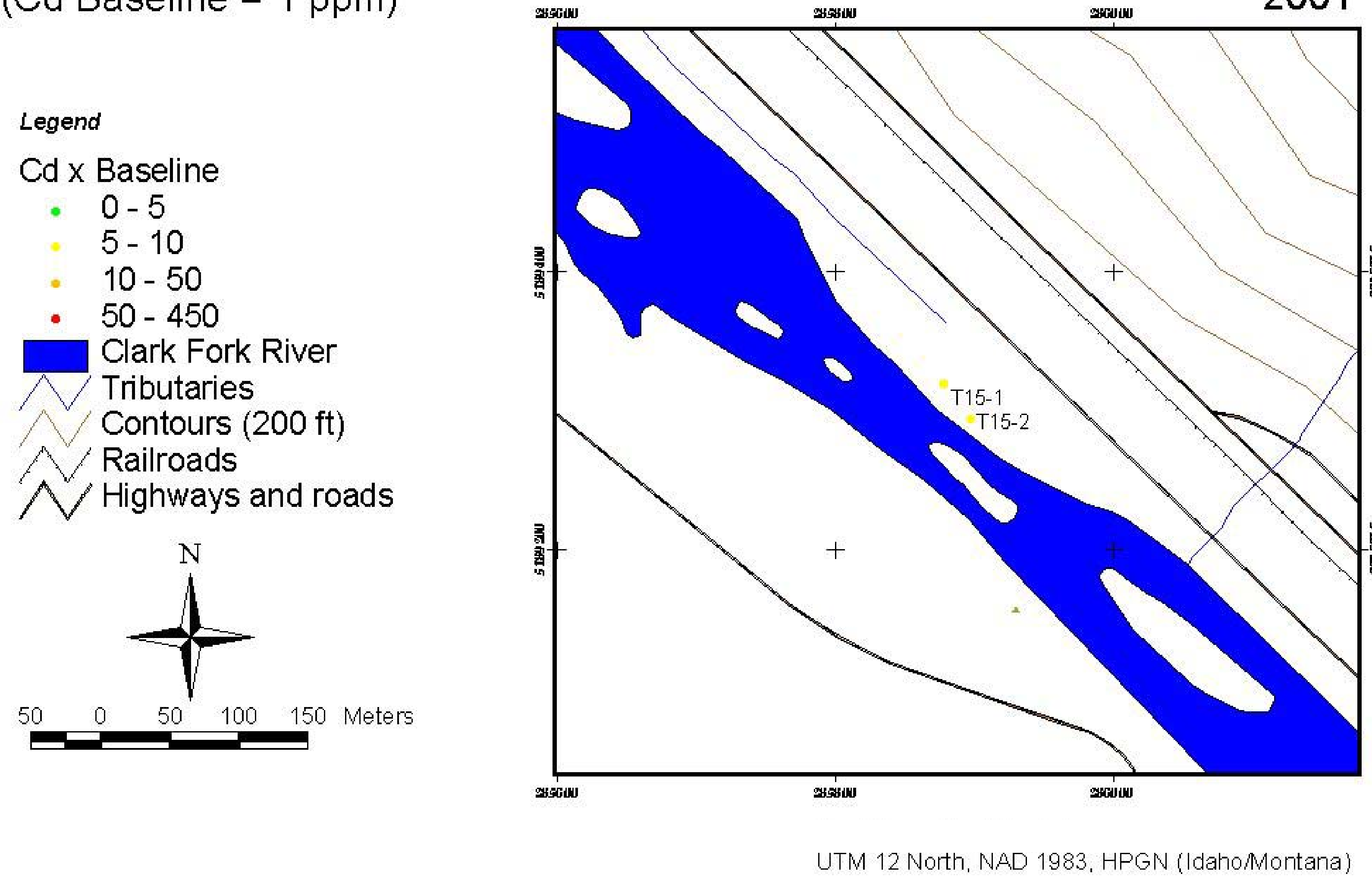


Figure III-73

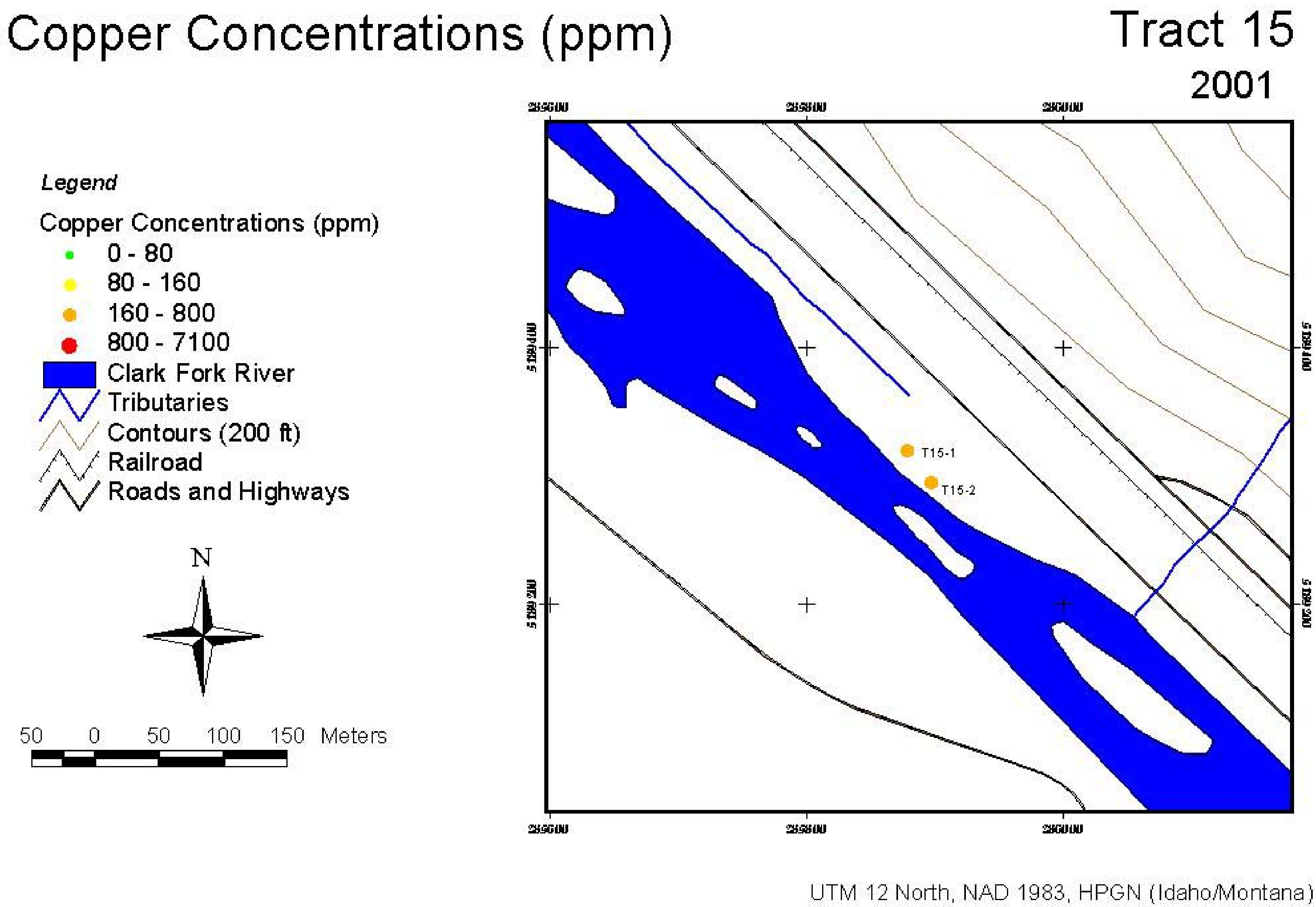


Figure III-74

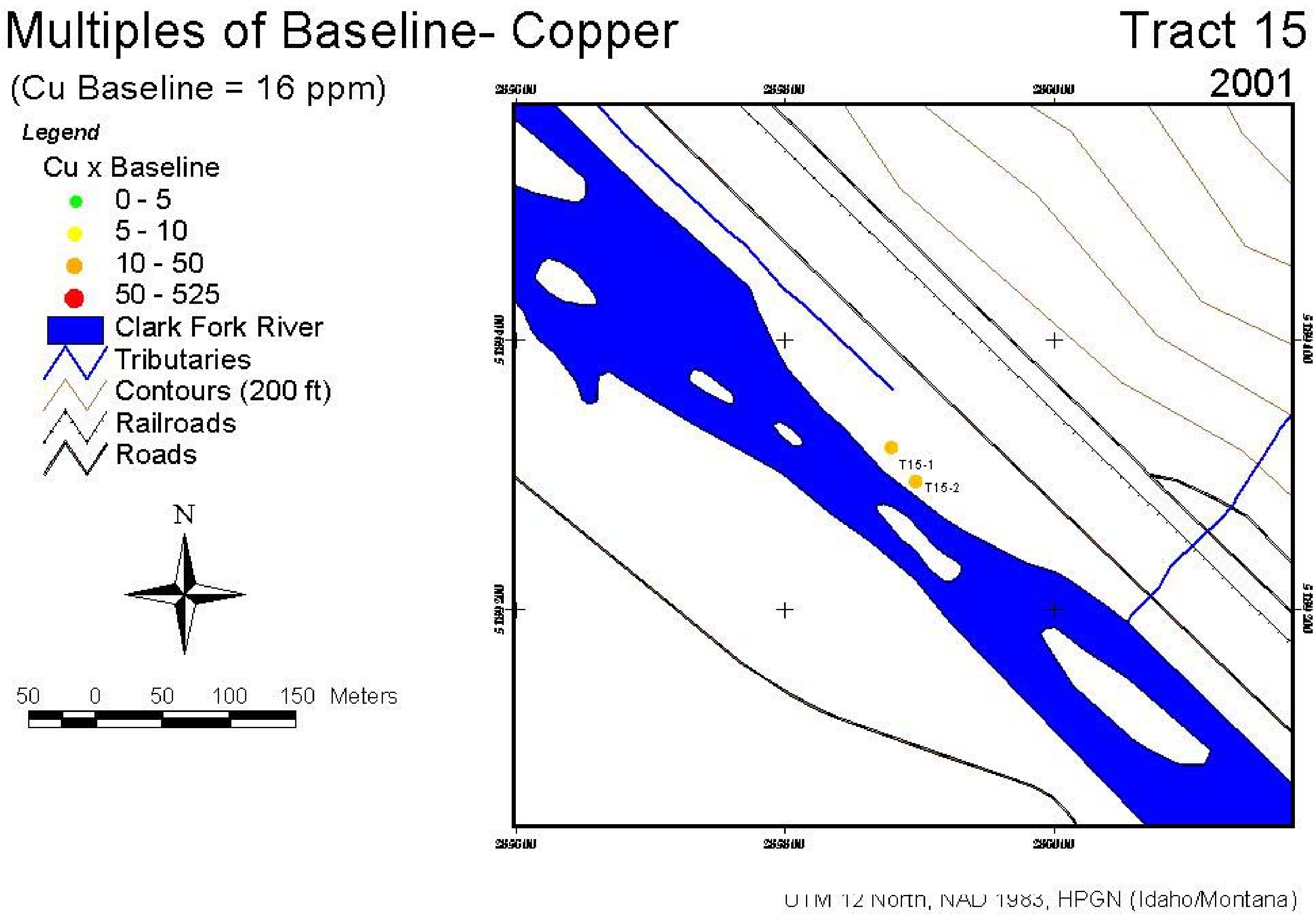


Figure III-75

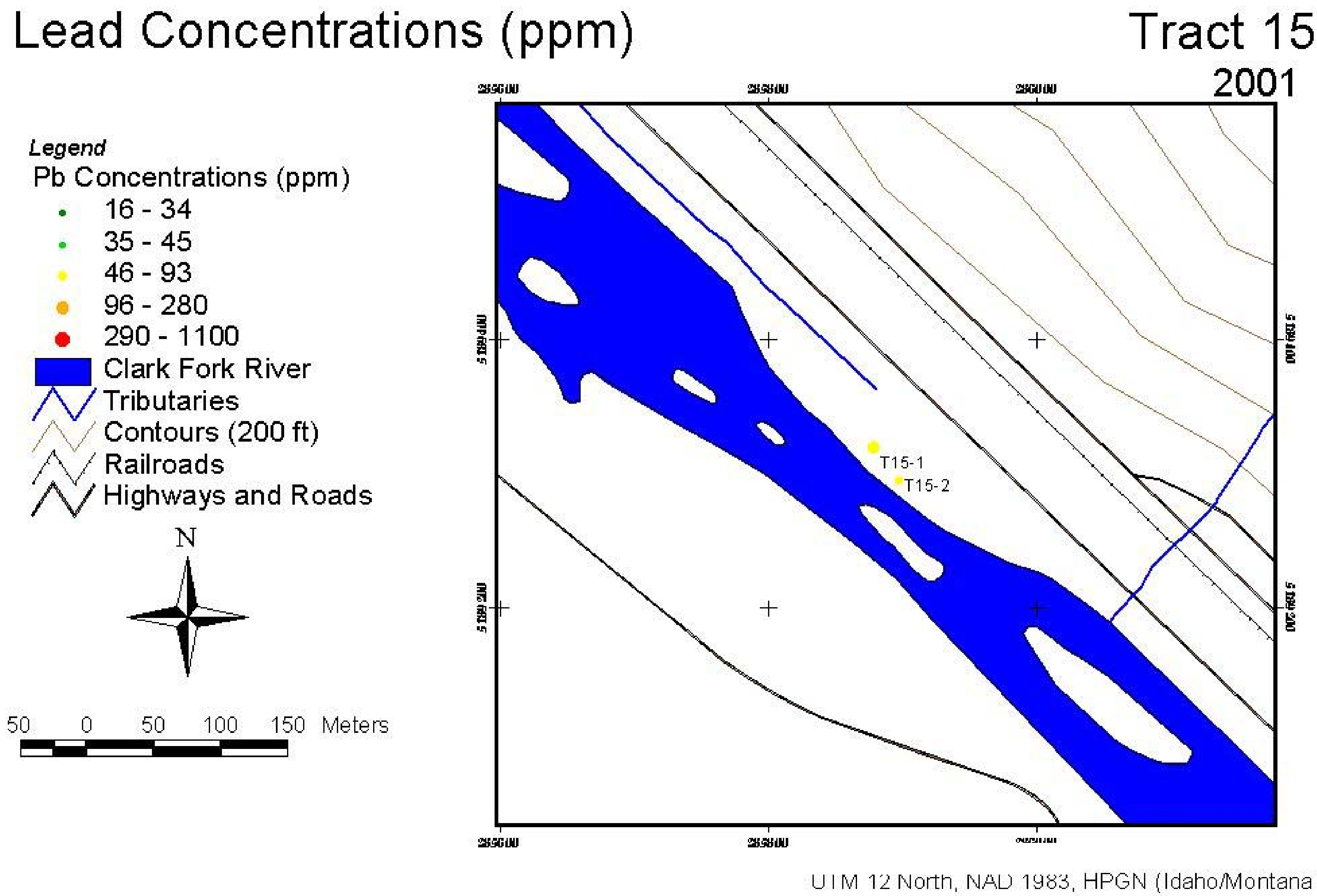


Figure III-76

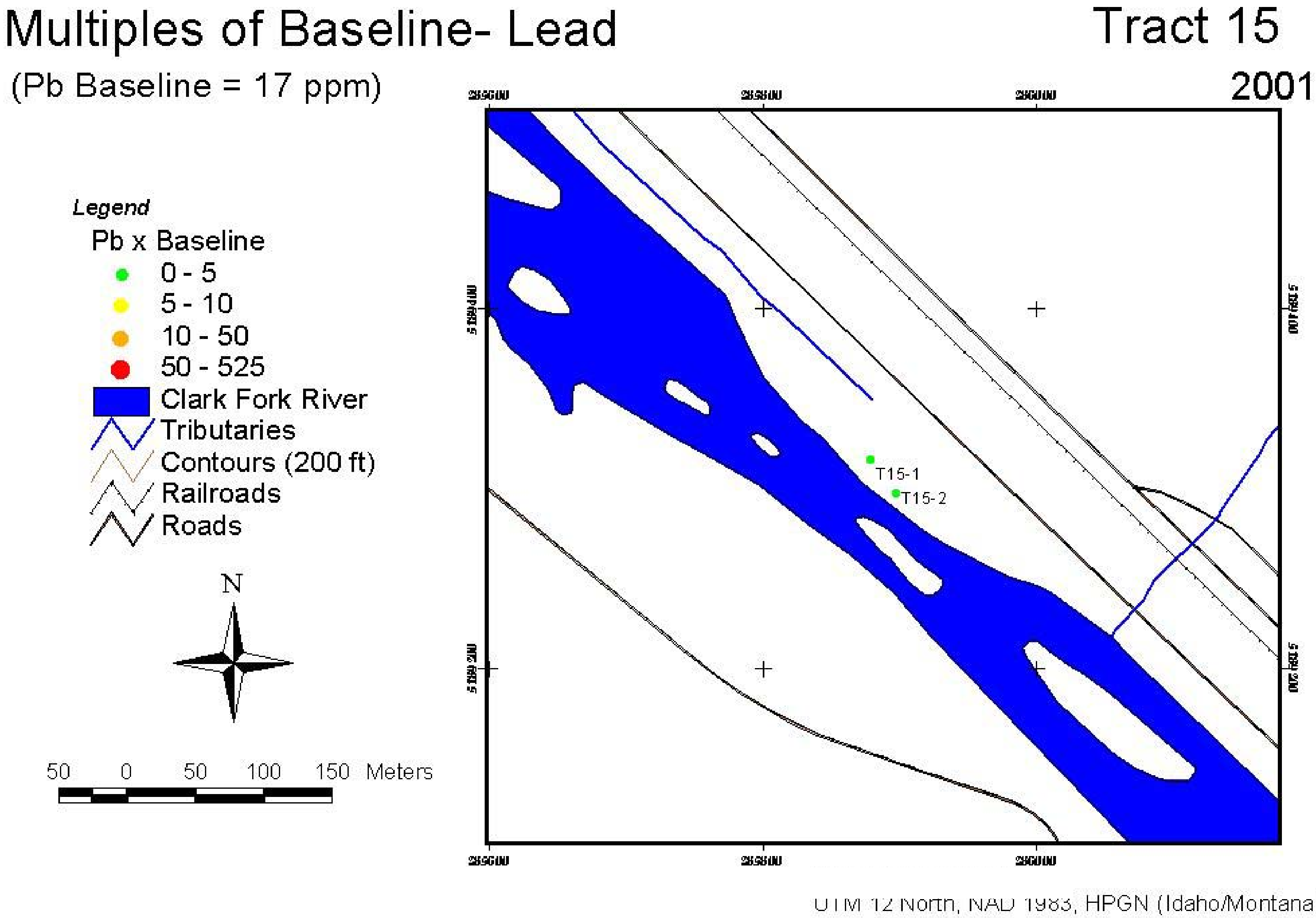


Figure III-77

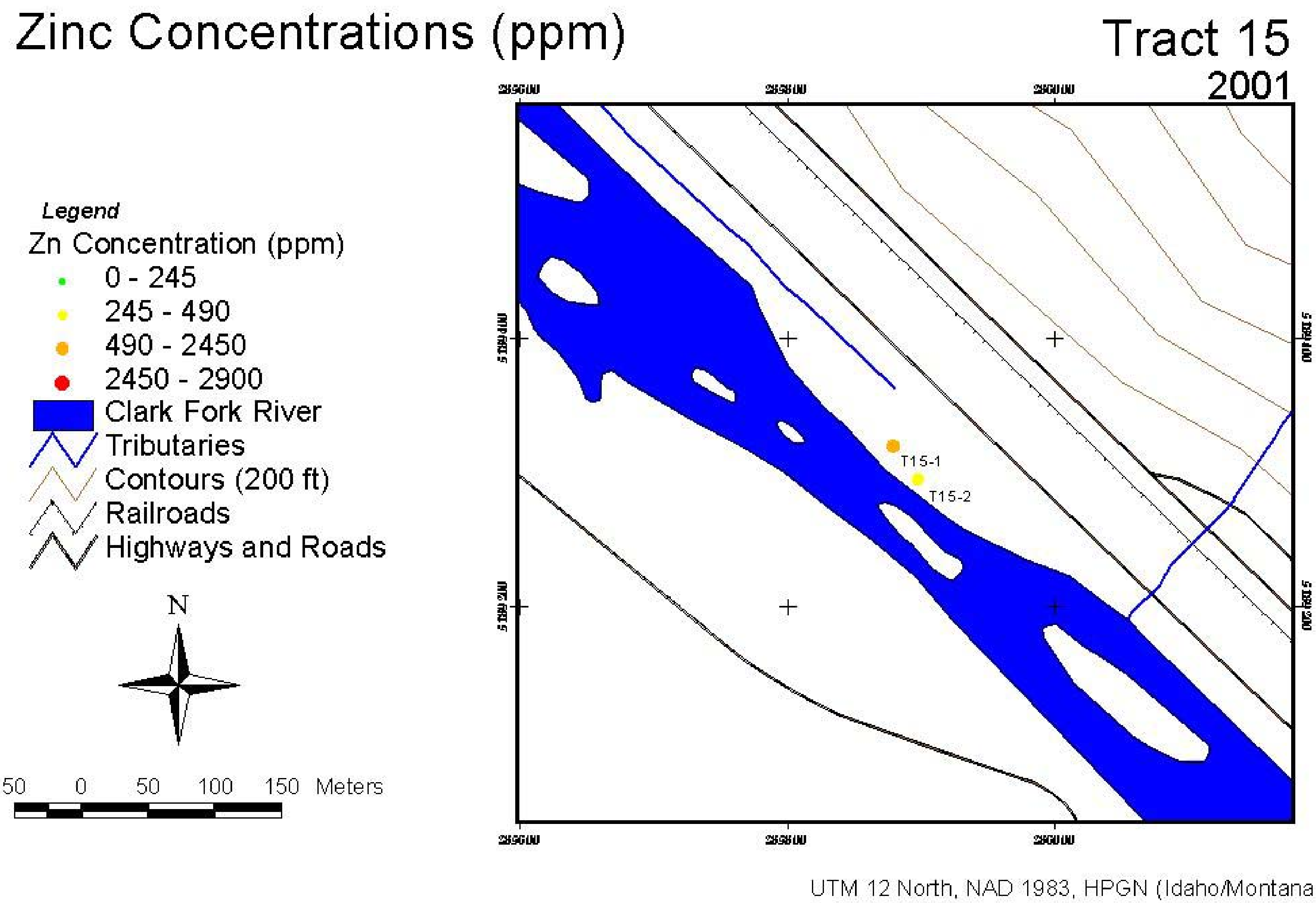


Figure III-78

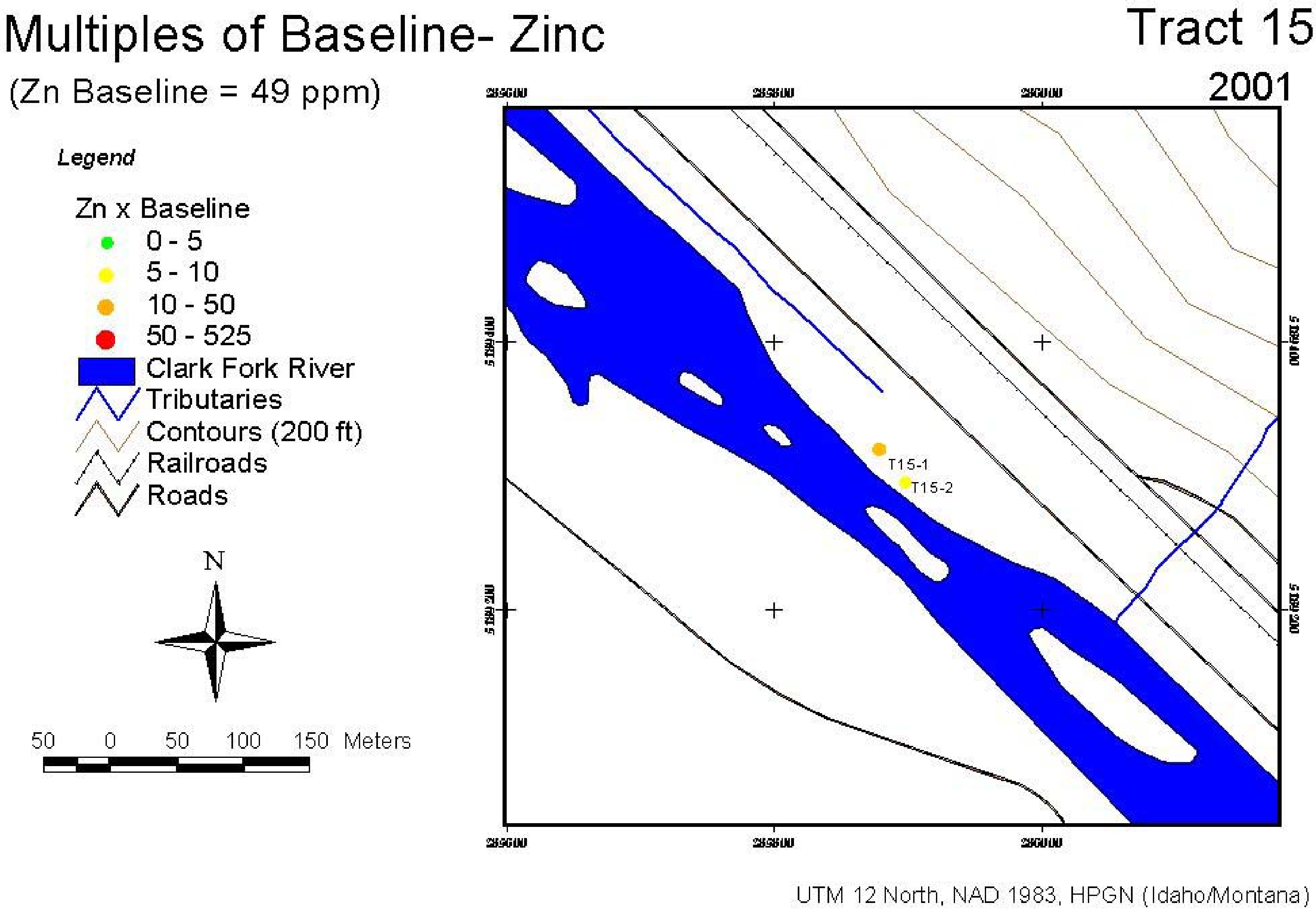


Figure III-79

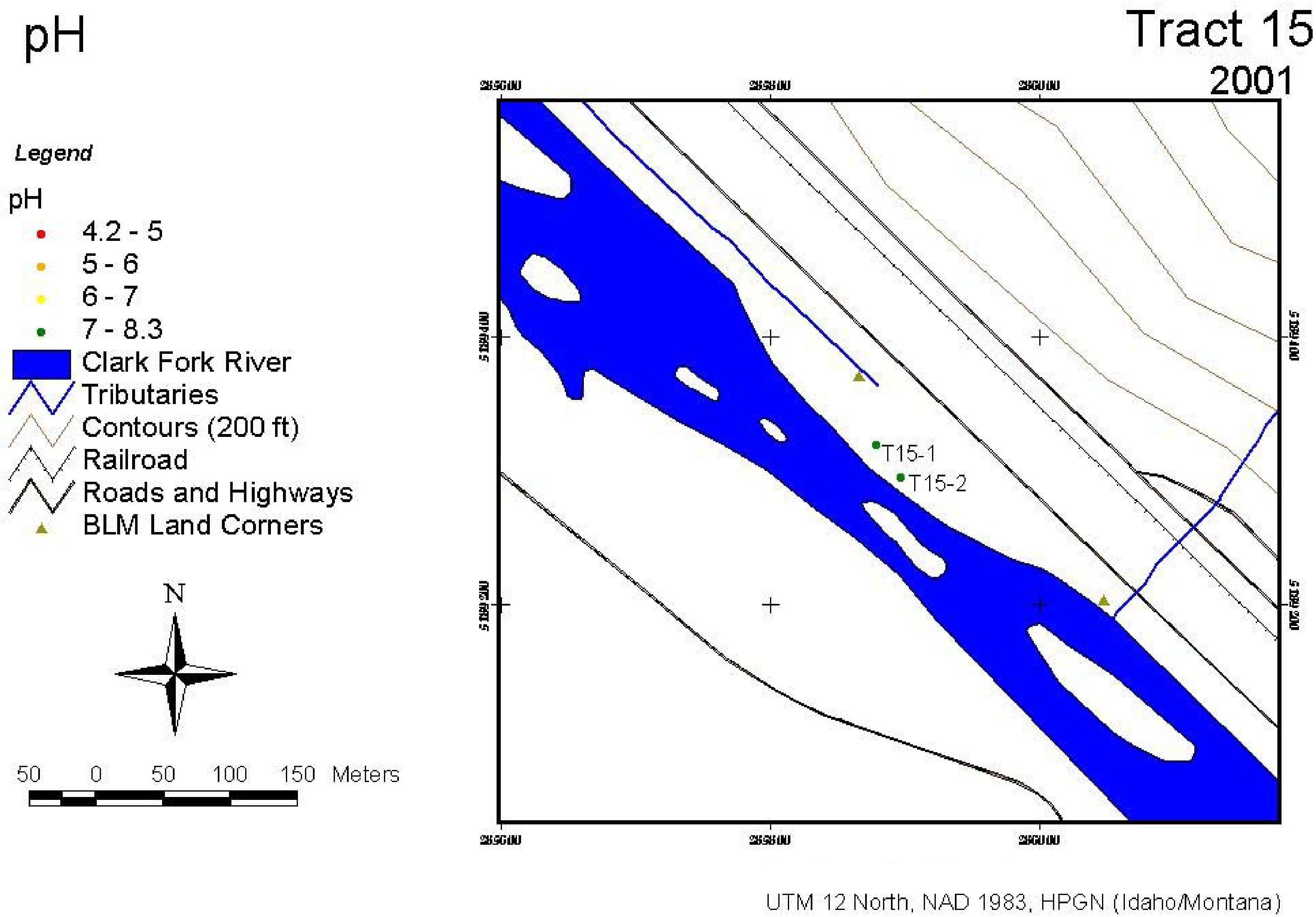


Figure III-80

CHAPTER IV

GEOMORPHOLOGY OF THE CLARK FORK RIVER CHANNEL AND FLOODPLAIN IN GRANT–KOHRS RANCH NATIONAL HISTORIC SITE

GEOCHEMISTRY AND FLUVIAL GEOMORPHOLOGY

REPORT

A DRAFT REPORT TO THE GRANT-KOHRS RANCH NATIONAL HISTORIC SITE

OCTOBER 24, 2001

BY

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Introduction

Previous observations at Grant-Kohrs Ranch showed that a significant portion of the banks along the Clark Fork River are undergoing erosion and that the morphology of much of the floodplain has been altered by deposition of mining wastes. The purpose of this work is to establish the processes causing bank erosion and the potential effects of vegetation cover and tailings thickness on erosion. A secondary purpose was to determine slickens extent and shape change through time.

Methods

Riverbanks along the Clark Fork River within Grant-Kohrs Ranch were classified based on river processes and bank shape. The banks were divided into depositional lengths (point bars) and erosional lengths (cut banks). Erosional banks were then classified as concave or convex based on their general shape (Figure IV-2). Breaks in vegetation cover were also used in defining bank segments, however, the boundaries were usually gradational. For each segment, visual estimates of the percentage of slumping, overhanging, and vegetation along the bank face were made. The percentage of woody vegetation cover within 2 meters of the bank was also estimated. Measurements of undercutting depth and tailings thickness were made with a Jacob's staff divided into 10 cm intervals, and the averages over the bank segment were noted. In this study, "overhanging" is the physical trait of being eroded underneath the bank, whereas "undercutting" is the amount of erosion under the overhang (Figure IV-6). Types of vegetation (shrubs, grass, forbs, etc.), evidence of tailings (salts, adjacent slickens, senescent/dead vegetation), and other attributes of each bank segment were also noted. Most of these measurements were visual estimates. The mapping and estimates were made by the same investigator to minimize the variability introduced by using different observers.

The riverbanks were mapped with a Trimble Pathfinder Global Positioning System (GPS) with a resolution of +/- 1 meter. While carrying the GPS, the researcher walked the top of the banks as close to the edge as possible (within about 1 m). The final GPS readings for the west banks were consistently offset up to 4 meters from the banks on the georeferenced 1997 Environmental Protection Agency (EPA) aerial photographs. This is likely due to errors in the georeferenced photo. The GPS data was later corrected to the 2001 aerial photographs taken specifically for this study (Map, Inc., 1613 South Ave. West, Missoula, MT). The GPS was also used to obtain gradient data for calculating the river's slope between the bridge and the north end of the study area. Vertical resolution was +/- 1 meter.

Changes in the channel morphology were detected by comparing EPA and NRCS aerial photographs from 1947, 1983, 1994, 1997, and 2001 (Table IV-1). The 1997 photo was provided by the EPA in a digital (600 dpi) georeferenced format. Older photos were obtained from the park service staff and scanned at 600 dpi. The 2001 pictures were taken in June by Map, Inc., and then digitized at 1200 dpi. Digital copies of the photographs were loaded into an ArcView Geographic Information System (GIS) and georeferenced by matching fixed points in the image to a grid position (i.e., latitude and longitude) using the ArcView Image Analysis extension. "Fixed" points, such as the corners of structures, fence corners, or vegetation on the scanned photographs were matched to the same points on the previously georeferenced 1997 EPA image. The program adjusts the pixel sizes to fit the new locations. After all the points were matched, the program calculated a root mean square (RMS) error for each point from the differences between the point on the image being referenced and its given location on the 1997 photograph. Initially, the pre-1997 photos were matched, in their entirety, to the 1997 image. White plastic sheeting, with 4 feet by 0.5 foot arms, were laid crosswise in and near the floodplain to act as ground control points in the 2001 photographs. The center of each cross was located by GPS, and these location data were used to reference the crosses on the digital image. Unfortunately, both of these methods resulted in total RMS errors of around 12 (~6m), which was too high for the precision needed. The high error was likely due to distortion in the aerial photographs.

Table IV-1. Aerial Photo Dates

Year	*Date*	*Discharge (cfs)*
1947	8/14/1947	na
1983	8/27/1983	301
1994	8/23/1994	45
1997	7/4/1997	841
2001	6/19/2001	158

To remove the error due to the distortion, the images were "clipped" into smaller pieces centered on the river, and then the smaller images were referenced to the 1997 photo. Most of the obvious fixed points (fences, buildings, etc.) were cut from the smaller images or were difficult to see, so georeferencing was done by matching shrubs or trees. For the most part, this method worked well. The total RMS errors for the smaller images, later than 1947, were less than 2.1, with most being around 1. An overall error was calculated by multiplying the highest RMS by the final pixel size for each year's images. The greatest overall error value was +/- 1.1 m. The poor quality (high altitude, low resolution) of the 1947 photos made georeferencing them much more difficult. The highest total RMS was 3.16 (1 m) and the worst point had an error of 6.9 (2.2 m). See Appendix IV-B for RMS data.

After the photographs were aligned, the next step was to digitize the banks in ArcView and calculate bank lengths. Each year's images were placed at a 1:300 scale and lines were drawn along the banks within the images. The 2001 banks mapped by GPS were adjusted to fit the morphology on the 2001 georeferenced images. A major problem with digitizing the banks this way, as with using shrubs to reference the photos, is that they are often difficult to see due to photo resolution, distortion, shadows, vegetation, and differences in water levels (Figure IV-14). Enlarging and rescanning the air photos at 1200 dpi and completing some image processing would possibly overcome some of the image problems. This was not done because we were unable to locate and obtain the negatives of the older photos to produce enlargements. The difference due to water levels is likely small because the discharges in 1983, the oldest photo used for analysis, and 2001, the most recent photograph, are similar (Table IV-1 and Figure IV-16). Riffles were mapped in the field on paper copies of the 1997 air photo, and then adjusted slightly to fit morphology on the georeferenced 2001 photographs. After the banks had been digitized, they were overlaid and in the straight reaches, where there are minimal water level effects, the lines were within 1 meter of each other.

After overlaying the banks from each set of photographs, relative bank positions were compared and areas of erosion were located and digitized within Arc View. Areas were selected only if the distance between the older bank and the 2001 bank was greater than the error of 1.1 meter, and if the banks seemed to be clearly retreating from the oldest banks to the youngest. Distances between the banks at meander bends were measured in ArcView and used to calculate the amount of bank retreat per year in these locations. ArcView was also used to calculate the total area of the floodplain lost to erosion.

The last aspect of the study was to investigate slickens dynamics. To accomplish this, the air photos were again reviewed and compared in ArcView. The same limitations, such as shadows, resolution, and color, that applied to georeferencing the photos and digitizing the banks applied to the slickens analysis. These problems made digitizing the actual slickens areas unreliable, so a more general analysis was completed by comparing shapes, vegetation cover and color, and dimensions of selected slickens areas. Adobe Photoshop was used to adjust the contrast, brightness, and color of the 1997 air photos, which were darker, so they would match the color of the other photos, and therefore, make it easier to see differences in vegetation.

RESULTS AND DISCUSSION

BANK INVENTORY

The banks along the Clark Fork River within Grant-Kohrs Ranch usually consist of four stratigraphic layers or units (Figure IV-1). The top layer (ca. 10 cm thick) is a sandy/silty, poorly consolidated soil, usually containing varying amounts of organic material and roots. The soil unit overlies a thicker layer (10 to 80 cm) of grayish-orange tailings composed of fine sand and silt. The tailings are usually lighter in color than the underlying units, and show orange and yellow mottling. Beneath the tailings lies a layer of grayish-brown silt/mud (20 to 50 cm) that is believed to be pre-mining floodplain deposits. A layer of sandy gravel and cobbles lies beneath the pre-mining floodplain deposits and is the lowest stratigraphic unit exposed in the banks. The thickness of the gravel/cobble unit is unknown, but is found throughout the entire study area. This stratigraphic package is prevalent throughout the riparian area and is seen in cores as well as bank exposures. The thickness of the various units is variable and any one unit may pinch out from one bank exposure to another.

The banks of the Clark Fork River within the Grant Kohrs Ranch National Historic Site were classified based on their morphology. Tables IV-2 and IV-3, and Figures IV-3 through IV-13 (indexed in Table IV-4) summarize the data. The entire inventory data set can be found in Appendix IV-A. The basic classification consists of two main types of banks, concave and convex (Figure IV-2). The convex banks tend to be found in the straight reaches of the river and along the inside bends of meanders. Concave banks are found on the outside of meander bends and where riffles direct the flow into the banks. An example of this distribution is shown in Figure IV-12. The straight channel in the lower half of the plate, point A, consists of convex banks, except where a riffle directs the water into the west bank, point B, where the bank is concave. Also, the banks associated with the meander at point C are convex on the inside of the bend (east bank) and concave on the outside (west bank). These general relationships extend throughout the entire reach of the Clark Fork River within Grant-Kohrs Ranch.

Table IV-2. Lengths of 2001 Surveyed Banks

Concave Banks	3145.96m
Convex Banks	6054.83m
Total Surveyed Banks	9200.79m

Table IV-3. Bank Attributes

Attributes of Concave Banks

total length=3145.96m	**mean**	**error**	**total length affected**
% of slumping along bank	43.46	10	1367.1
% of overhanging along bank	28.49	10	896.4
% of bank face with vegetation cover	38.57	10	1213.51
% of bank with woody vegetation within 2 m	19.85	15	624.49
avg thickness of tailings (cm)	44	10	
avg depth of cutting under overhangs (cm)	30	10	

Attributes of Convex Banks

total length=6054.83m	**mean**	**error**	**total length affected**
% of slumping along bank	4.59	10	277.8
% of overhanging along bank	45.86	10	2776.67
% of bank face with vegetation cover	83.6	10	5062.01
% of bank with woody vegetation within 2 m	32.34	15	1958
avg thickness of tailings (cm)	36.82	10	
avg depth of cutting under overhangs (cm)	34.89	10	

Table IV-4. Index to Bank Inventory Figures

Figure IV-3	Convex and Concave Shapes
Figure IV-4	Percentage of Overhanging Along Bank
Figure IV-5	Depth of Undercutting
Figure IV-8	Percentage of Slumping Along Bank
Figure IV-9	Tailings Thickness
Figure IV-12	Percentage of Vegetation Cover at Bank
Figure IV-13	Percentage of Shrubs within 2m of Bank

Overall, the river bank inventory included 9200 m of banks, of which 3145 m (34%) were concave "cutbanks" and the remaining 6045 m (66%) (Table IV-2) were the more stable convex shapes (Figure IV-3). Both bank types are susceptible to undercutting (Figures IV-4 and Figure IV-5) and therefore, a large portion of each type can be described as overhanging (Figure IV-6). Most of the erosion initiates in the lower gravel and mud layers, which often leaves the tailings, soil, and vegetation overhanging the river. These overhanging banks occurred in 46% of the convex segments, with cuts typically 30cm in depth at the base of the bank. Overhangs occurred in only 28% of the concave bank segments, but they also had a typical cut depth of about 30 cm. However, concave-bank undercuts usually occur in the middle portion of the bank and are not as clearly defined as those seen in convex banks. As mentioned previously, most of the undercutting takes place in the gravels and old floodplain deposits, which leaves the more resistant tailings layer overhanging. These overhangs eventually slump into the river (Figure IV-7 and Figure IV-10). The percentage of slumping along the banks is shown in Figure IV-8. Despite the higher percentage of overhangs, the convex segments possess slumps along only 5% of the banks, whereas slumps are present along 43% of the concave banks. Slumping mostly occurs at riffles and meander bends where cutbanks are forming and there is a strong relationship between concave banks and slumping (Figure IV-3 and IV-8).

Tailings can be found in almost all of the banks exposed along the river (Figure IV-9). Where exposed in cutbanks or animal paths, the average tailings thickness is 37 cm, although these vary between 10 and 80 cm. The areas that lack tailings include a few short lengths where the channel has eroded into the edge of the meander belt (Points A and B, Figure IV-9a and Point A, Figure IV-9c), and near the constructed sewage ponds at the north end of the park (Point C, Figure IV-9a). Tailings thicknesses were measured rarely in the convex banks because tailings were generally not exposed. However, many of the bank segments exhibited evidence of tailings, such as adjacent slickens areas, salts forming on the lower banks (Figure IV-11), senescent/dead vegetation, and tailings indicative vegetation (i.e., tufted hairgrass (*Deschampsia cespitosa*)) or small exposures in animal paths.

Visual estimates were made of vegetation on the bank face, and woody vegetation within 2 meters of the bank. Woody vegetation consists mostly of small (~1 m high) water birch (*Betula occidentata*) and various willows (*Salix* sp.)The rest of the vegetation is dominated by various grasses. Figures IV-12 and 13 summarize these data. Convex banks were commonly more vegetated than the concave banks (84% vs. 39%, respectively), and had more woody vegetation within 2 m of the bank (32% vs. 20%, respectively).

CHANNEL MIGRATION

To calculate the changes in channel position, the aerial photographs were digitized and then the banks were drawn on each of the digital photos. The four images in Figure IV-14 show the change in channel position (they also give some indication of the problems with image quality, color, shadows, water level, etc., that often made locating the banks a difficult task). The digitized bank lines were then overlaid, and the areas between the older bank lines and the 2001 bank lines were digitized. The meander depicted in Figure IV-14, labeled "Northbend," is also shown in Figure IV-15. This figure gives an example of the overlaid banks and the corresponding areas of erosion. It clearly shows a retreating bank on the outside of the meander and an advancing point bar on the inside. Between 1983 and 1994, there were 435 m^2 of sediment eroded from the east bank, from 1994 - 1997, 623 m^2 were removed, and from 1997 to the present, the bank lost 102 m^2 of material (Table IV-5). The large amounts of erosion in the first two time intervals seem to correspond to high flows in 1986 and 1997 (Figure IV-16). Figure IV-17 shows some examples of the distance of bank retreat. The average rate over all six locations is 0.5 meters/year. This rate is consistent with changes since 1947 (Figure IV-16). The "Northbend" meander in Figure IV-16 has migrated 40 meters since 1947. Again, it is important to note that the point bar is also advancing at similar rates, basically balancing erosion on the outside of the meander with deposition on the inside.

Erosion areas were digitized wherever there seemed to be significant distances (>1.1 m) between the older bank lines and the 2001 banks and where banks were obviously retreating between 1983 to 2001. Figure IV-19 shows the amount and location of riverbank erosion at Grant-Kohrs Ranch, and the riffle location and flow direction. It is apparent from these maps that the major control on bank erosion is the channel morphology. Specifically, major areas of erosion seem to occur where the shallow, turbulent riffles direct the water into the bank, and in outside of meander bends. Good examples of erosion due to the riffles can be seen at point A in Figure IV-19a, point A in Figure IV-19c, and points A and B in Figure IV-19d. The tight bend at point B in Figure IV-19c ("Northbend") is a good example of erosion on the outside of a meander bend. The most common cause of bank erosion is the combination of meander bends and riffles. Good examples are depicted at point A in Figure IV-19a, point C in Figure IV-19d ("Stuart Field") and the bends north of point B in Figure IV-19d. In river reaches where the channel is straight, with no riffles, there tends to be very little erosion. This can be seen in the straight reach in the southern half of Figure IV-19b. Where a riffle exists at point B, the channel is beginning to widen. There are also a few meander bends without riffles where less erosion is taking place, such as at point C on Figure IV-19a. The channel here is relatively deep and the water velocity at the time of study was extremely slow.

The amount of land lost to channel migration can be calculated by combining all of the areas or eroding banks seen in Figure IV-19. For example, "Northbend" has lost 0.29 acres, "Stuart Field" has lost 0.24 acres, and the bend just south of the park bridge ("Bridge South") has lost 0.22 acres (Table IV-5). The data shows that 3.1 acres (12.6×10^3 m^2) of material have been eroded from the banks since 1983. It is important to note in Figures IV-15, 17, and 19 that the area of erosion is approximately balanced by the area of deposition in the point bars. Therefore, unless the volumes of material are different, it appears that there is little net loss of land from Grant-Kohrs Ranch, but the floodplain terraces are being rapidly reworked by the river.

Table IV-5. Erosion at Selected Meander Bends

	1997-2001		1994-2001		1983-2001			
	m^2	*acres*	*m^2*	*acres*	*m^2*	*acres*	*acres/yr*	*m^2/yr*
TOTAL	732.837	0.181	6973.742	1.723	12643.842	3.120	0.173	702.44
Farnorth	77.744	0.019	124.512	0.031	797.739	0.197	0.011	44.32
Southbridge	57.385	0.014	376.571	0.092	848.382	0.222	0.012	47.13
Stuart Field	62.099	0.015	584.154	0.144	951.064	0.235	0.013	52.84
Northbend	101.625	0.025	723.937	0.179	1158.849	0.286	0.016	64.38

Woody vegetation does not seem to be a major component in stabilizing the riverbanks in Grant-Kohrs Ranch. Figure IV-20 compares erosion at banks with varying levels of woody vegetation. At “Bridge South” shrubs dominated the bank in 1983, but by 2001 they have been eroded, so are no longer along the bank. “Northbend” lost a moderate amount of woody vegetation since 1983 as well (Figure IV-20). This figure also shows that banks without shrubs (“Stuart Field”) erode at similar rates to those with woody vegetation. Figure IV-12 depicts the reach within the park and the percentage of woody vegetation along each bank segment. These maps reveal that erosion areas do not seem to favor one level of woody vegetation over another. One factor that could affect this is the size of the vegetation and the penetration of roots. Woody vegetation along the bank often consists of short willows and water birches, usually not more than a meter high (Figure IV-21). Even in areas with relatively tall or dense vegetation, the banks, especially the tailings and lower areas, are devoid of living roots ehich otherwise would hold the sediments in place (Figure IV-1 and Figure IV-22). Most of the erosion initiates in the lower gravels and muds which underlie the roots. The river erodes underneath them and the plants slump into the river with the rest of the bank sediment (Figure IV-7). The convex banks were more vegetated than the concave banks (see bank inventory section), however, this does not necessarily explain the stability of the convex banks. In fact, it may be the opposite: Convex banks support more plants because they are stable and concave banks cannot maintain vegetation because they are constantly eroding.

Thickness of tailings also does not seem to play a direct role in controlling bank erosion. Tailings are present along most of the river channel within the park. Figure IV-9 shows the different thicknesses of tailings found in the cutbanks. These thicknesses do not seem to affect the occurrence or amount of erosion (Figure IV-9). However, there is one length of bank in the northeast corner of the park where there are no tailings ("Ponds") that has less erosion than a similar bend with the same basic types and amounts of vegetation ("Stuart Field"), farther upstream (Figure IV-23). Unfortunately, this is not a good comparison due to other factors that may be at work at "Ponds." Bank migration is constrained by riprap and ponds constructed for waste water treatment directly north of the bank. Also, unlike most of the meander bends in the park reach, there are no riffles in this particular bend (Figure IV-19a, point C). Instead, the water gets deeper and much slower through the meander, forming a large pool.

One way that the tailings have affected the banks is by building up the floodplain, and therefore effectively "lowering" the water table. Plant roots now have to grow much deeper, through a layer of contaminated soil, to reach groundwater and to stabilize the mud and gravels in the lower portions of the bank. The plants that cannot reach the water table also may become more susceptible to disturbances, such as drought and fire.

Slickens Dynamics

Besides looking at channel changes, slickens dynamics were also investigated. It was difficult to quantify changes in slicken size and extent due to problems with image resolution, quality, color, etc. However, changes in slickens areas and vegetation cover were obvious on the aerial photographs. The 1947 photos were used to examine slickens dynamics over a long time period, but poor photograph quality made this task difficult. Lengths and widths of a few selected slickens were measured and compared, but given the poor photo resolution, there appears to be little significant change (Figure IV-24). Detectable differences are subtle, such as two new bushes on the east side of Box A in "Northbend" in 1983, 1994, 1997, and 2001. For the most part, the size and shape of the slickens remain the same from 1983 to 2001. However, the slickens are not static. Barren areas and areas of stressed vegetation appear to change as they respond to disturbances. Perturbations, such as droughts and fires seem to have a major effect on vegetation coverage and slickens extent. Moisture levels seem to be a major control with the changes seen in Figure IV-25. The amount of precipitation (Figure IV-26) and discharge in the river (Figure IV-16 and Table IV-1) indicate that there was much more water available for vegetation before and at the time the 1997 photographs were taken, compared to the other photographs. In the 1983 and 1994 pictures, there appears to be a mix of flourishing and senescent/dead vegetation, and the slickens appear to be the same basic size and shape. The 1997 aerial photographs exhibit larger shrub canopies, more grass coverage, and more vegetation coverage in general. The 2001 image reverts back to large areas of senescent/dead vegetation and the slickens appear to be slightly larger. In 1997, Box A (Figure IV-25) shows the larger canopies and increased vegetation, especially at the riverbank and around the shrubs in the lower portion of the box, compared to the other years. Also, shrubs that appear to be flourishing in 1997 appear gray and leafless in the other photographs (Box B and the west side of Box C).

Figure IV-27 shows changes in response to a fire that burned the area in 1998. Slickens developed after this fire. The images show the same trends as the other photos (Figure IV-25). Shrub canopies and vegetation seem to increase dramatically between 1983 to 1997. Then, in 2001, the barren areas increase in Box A compared to the older photographs. This change is likely due to the combination of fire and drought. The fire seems to have exacerbated the dry conditions and therefore, the numbers and sizes of the slickens appear to have increased (Figure IV-27). Comparisons of Box B (Figure IV-27) clearly show the changes from mixed healthy and senescent shrubs in 1983, to flourishing shrubs in 1997, to mostly senescent and dead shrubs in 2001 without the additional affects of fire.

CONCLUSION

There are several conclusions that can be made from the observations made on channel and floodplain morphology. First, there is a large amount of channel migration. The outside of meanders are eroding at approximately 0.5 meters/year. This results in about 3.0 acres of floodplain being removed each year. At the forementioned rates, it will take around 800 years to rework the Grant-Kohrs Ranch floodplain, and its tailings, once. This erosion is approximately balanced by the deposition of new material on the point bars, so that there is no measurable net loss of land. However, the land along the river meander belt is definitely transformed.

The position of eroding banks is controlled dominantly by the morphology of the river channel. The coincidence of riffles on meander bends are associated with the largest amount of bank erosion and cutbank formation. The presence of vegetation and tailings thickness seem to have very little affect on the position and amount of erosion. Cutbank formation appears to be a combination of undercutting of the bank by high flows and the slumping of material into the channel. The unconsolidated/non-cohesive gravel and pre-mining floodplain deposits at the base of the banks are easily eroded, leaving overhangs that can slump/cave into the river channel. It will be very difficult to stabilize the banks unless the erosion of these lower levels can be slowed. Presently, it appears that the banks are unstable because of the lack of deep-penetrating roots into the lower layers. The deposition of tailings on the floodplain has elevated the floodplain surface, exacerbating the effects from metals loading and preventing deep rooted plants from reaching moisture and stabilizing the lower levels of the banks.

Vegetation cover and slicken size appear to be mostly controlled by moisture. The major dimension of slickens are relatively stable over the time interval studied (1947-2001). However, vegetation cover definitely changes over time in response to wetter or dyer conditions. During dry years, woody vegetation is senescent/dead inslicken areas but grows again during wet years. Many areas that are bare slickens in the dry years appear to be covered with grass when moisture increases. These changes in vegetation seem to be enhanced by fire. In one area where a fire occurred, slickens appeared to be larger in the dry years following the fire than the dry years proceeding the fire. These observations show that the slickens are very dynamic and will change due to forcing by climatic conditions.

In general, the floodplain system is dynamic and rapidly changing. The rate of channel migration and vegetation cover is controlled by river flow and precipitation. Managing this rapidly-changing system to minimize the effects of metal-contaminated floodplain soils requires that this dynamism be taken into account.

CHAPTER IV-FIGURES

GEOMORPHOLOGY OF THE CLARK FORK RIVER CHANNEL AND FLOODPLAIN IN GRANT–KOHRS RANCH NATIONAL HISTORIC SITE

GEOCHEMISTRY AND FLUVIAL GEOMORPHOLOGY REPORT

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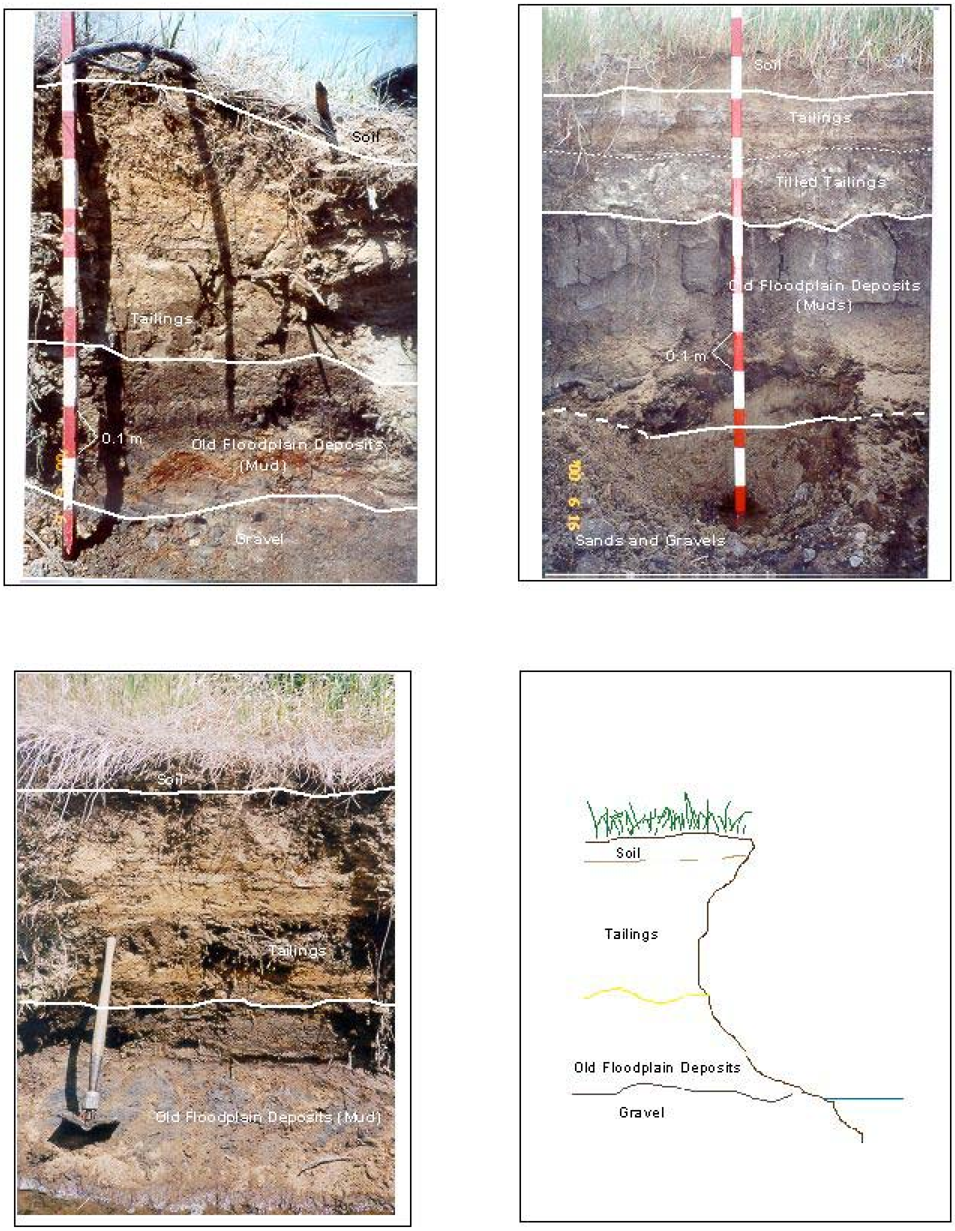


Bank Stratigraphy Examples

Figure IV-1

Examples of Concave and Convex Banks

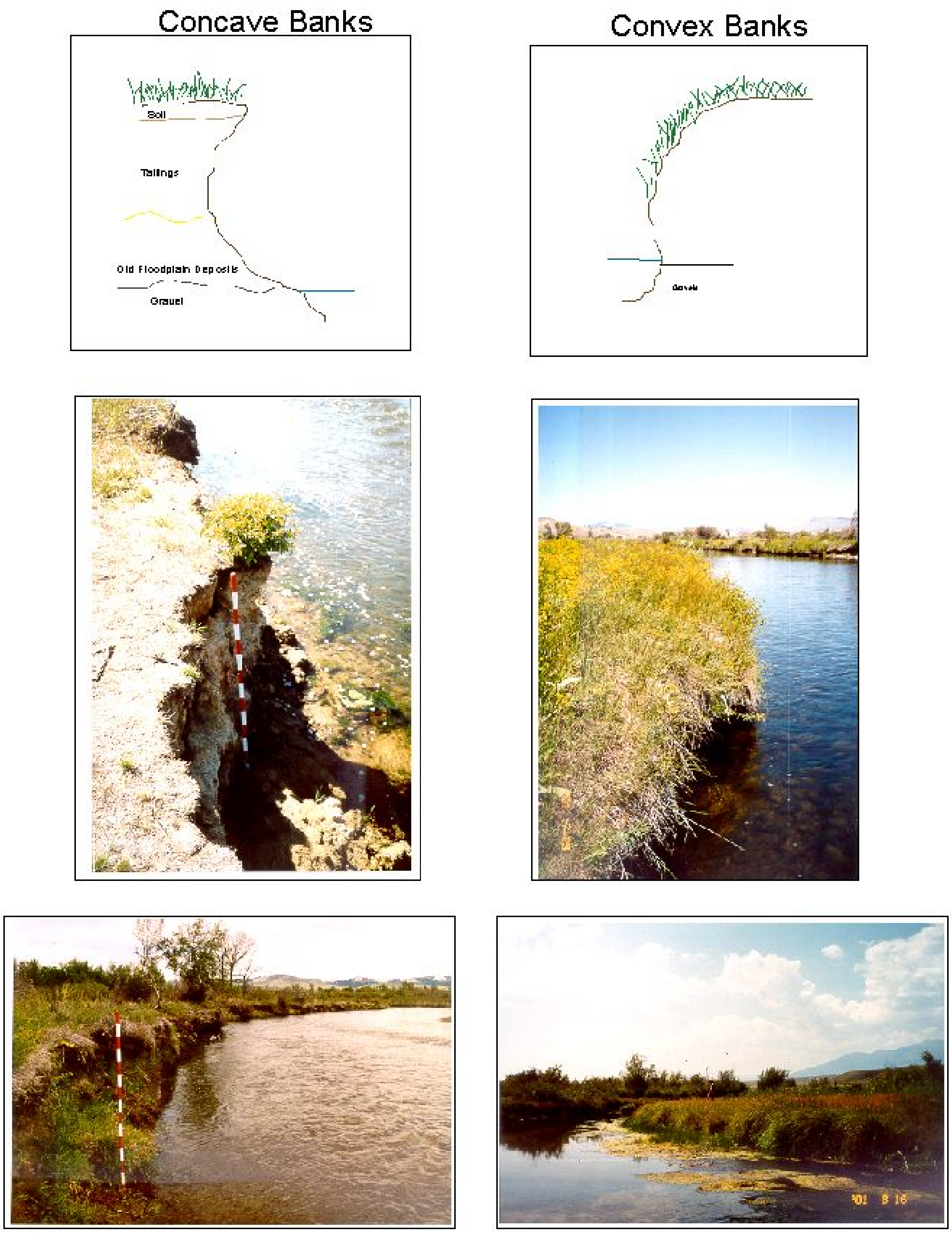


Figure IV-2

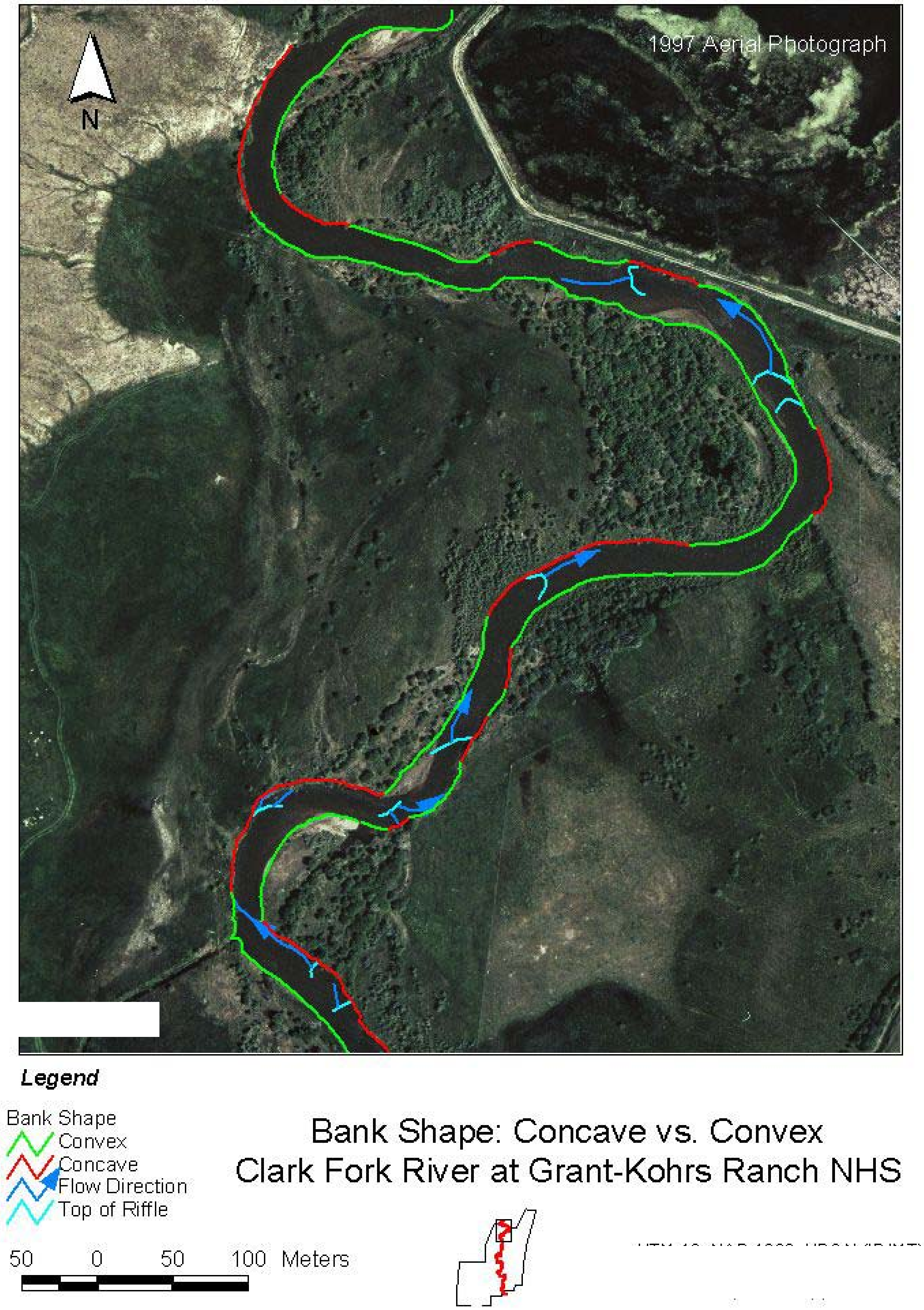

1997 Aerial Photograph
N
Legend
Bank Shape
Convex
Concave
Flow Direction
Top of Riffle
50 0 50 100 Meters
Bank Shape: Concave vs. Convex
Clark Fork River at Grant-Kohrs Ranch NHS

Figure IV-3a

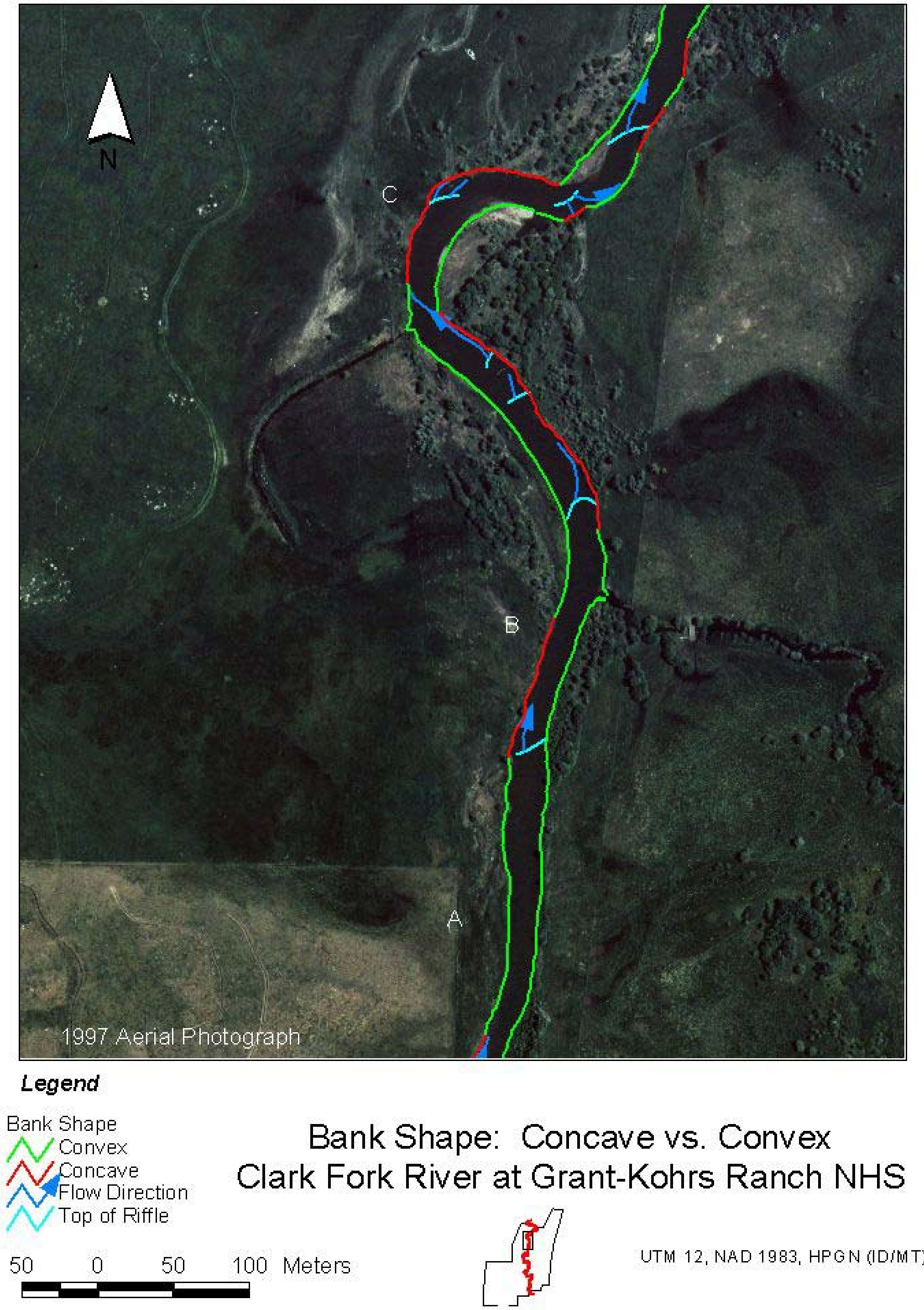

N
C
B
A
1997 Aerial Photograph
Legend
Bank Shape
Convex
Concave
Flow Direction
Top of Riffle
50 0 50 100 Meters
Bank Shape: Concave vs. Convex
Clark Fork River at Grant-Kohrs Ranch NHS
UTM 12, NAD 1983, HPGN (ID/MT)

Figure IV-3b

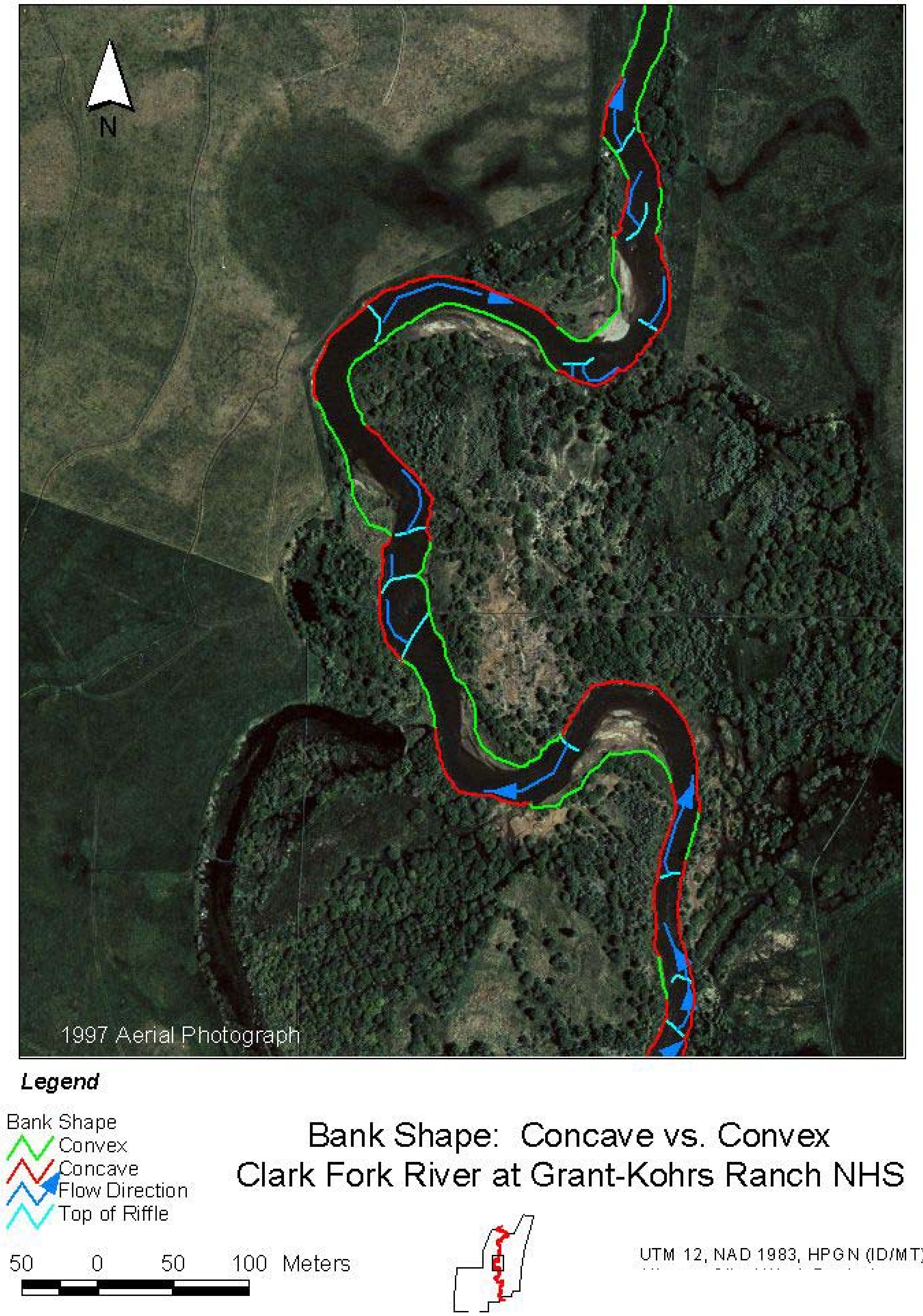

N
1997 Aerial Photograph
Legend
Bank Shape
Convex
Concave
Flow Direction
Top of Riffle
Bank Shape: Concave vs. Convex
Clark Fork River at Grant-Kohrs Ranch NHS
50 0 50 100 Meters
UTM 12, NAD 1983, HPGN (ID/MT)

Figure IV-3c

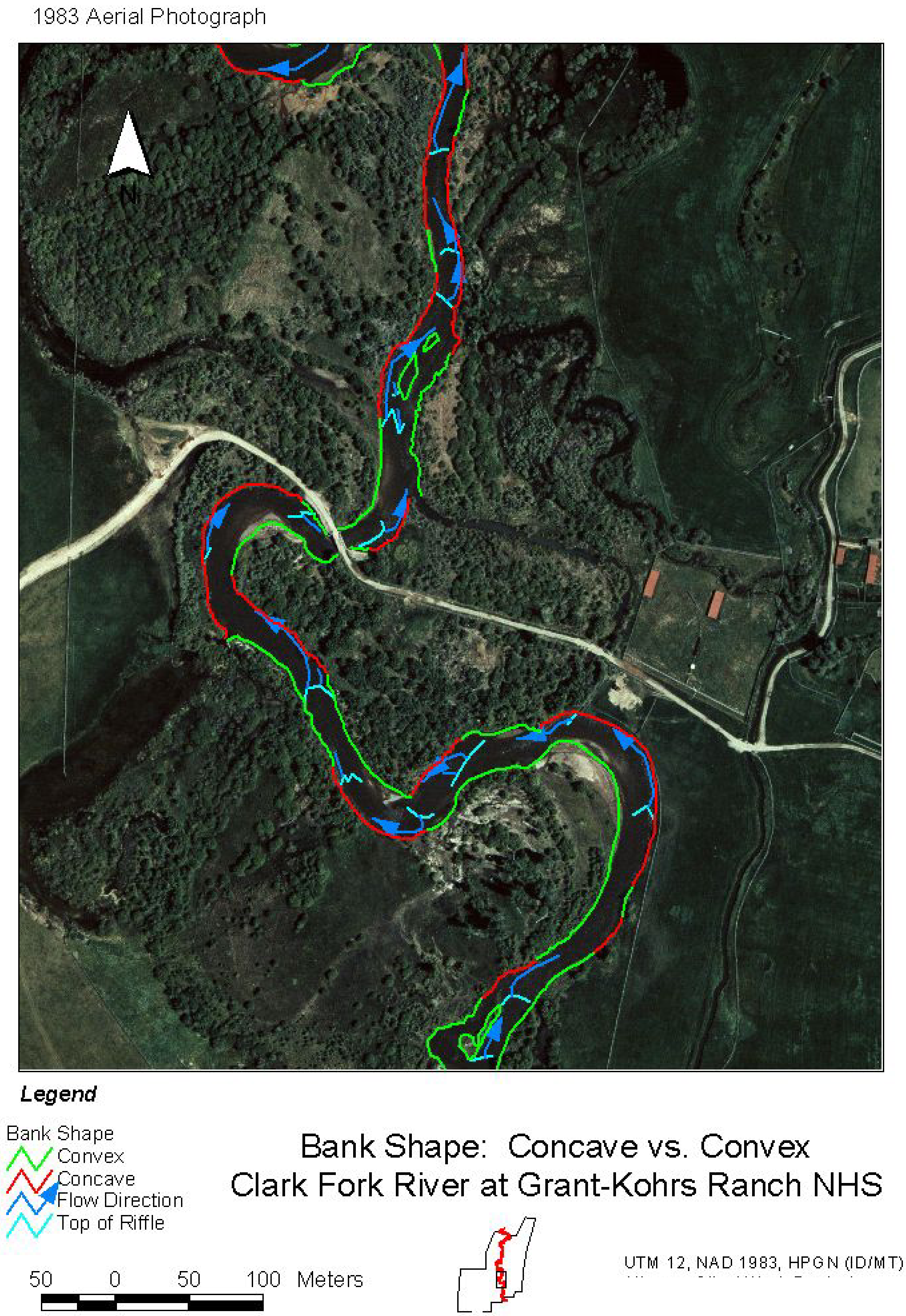

1983 Aerial Photograph
N
Legend
Bank Shape
Convex
Concave
Flow Direction
Top of Riffle
Bank Shape: Concave vs. Convex
Clark Fork River at Grant-Kohrs Ranch NHS
50 0 50 100 Meters
UTM 12, NAD 1983, HPGN (ID/MT)

Figure IV-3d

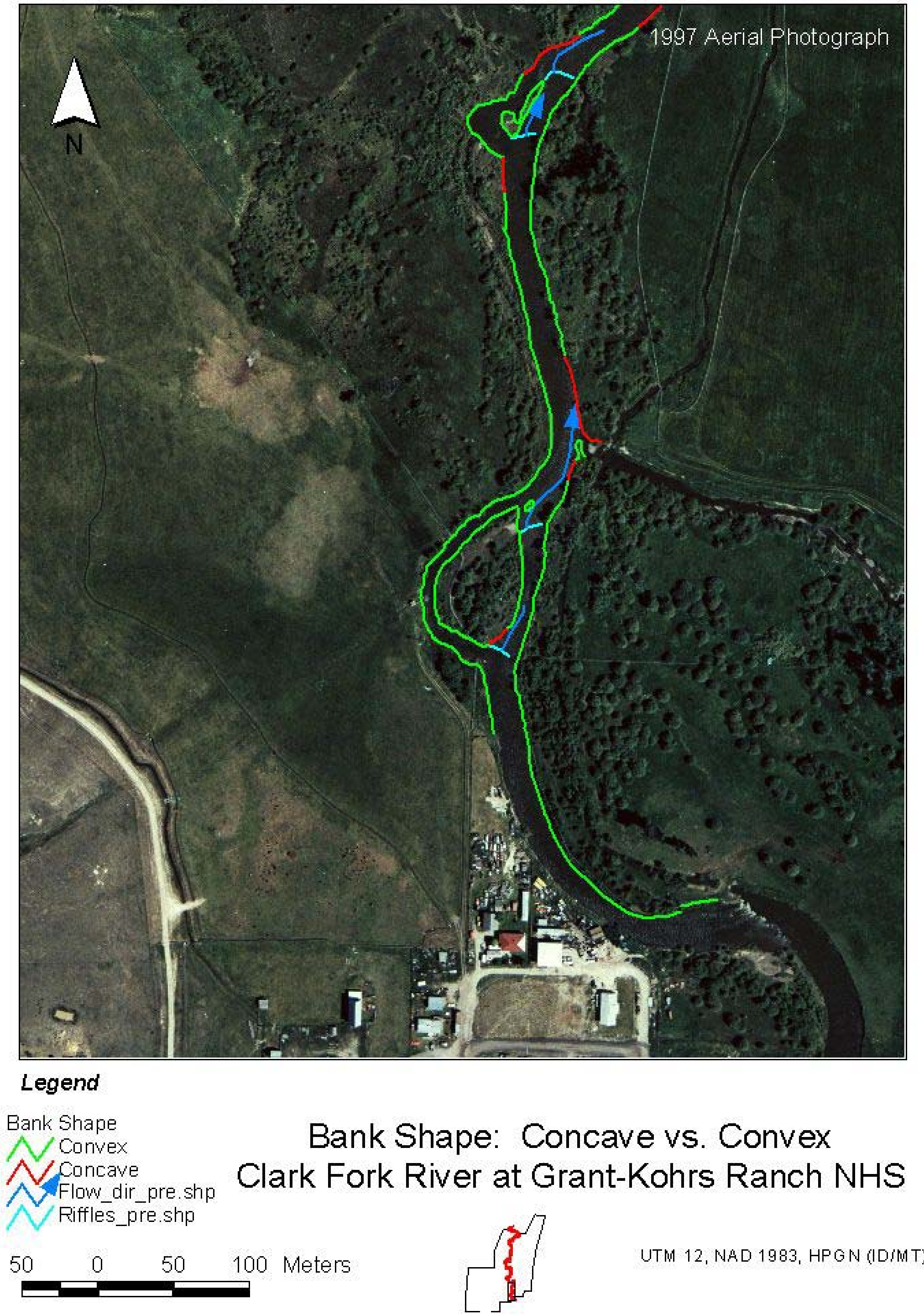

1997 Aerial Photograph
N
Legend
Bank Shape
Convex
Concave
Flow_dir_pre.shp
Riffles_pre.shp
50 0 50 100 Meters
Bank Shape: Concave vs. Convex
Clark Fork River at Grant-Kohrs Ranch NHS
UTM 12, NAD 1983, HPGN (ID/MT)

Figure IV-3e


1997 Aerial Photograph
N
Legend
Percentage of Overhanging Along Bank
0 - 10%
11 - 30%
31 - 60%
61 - 80%
81 - 100%
Average Percentage of Overhanging Banks
Clark Fork River at Grant-Kohrs Ranch NHS
50 0 50 100 Meters
UTM 12 NAD 1983 HPGN (ID/MT)

Figure IV-4a

1997 Aerial Photograph
N
Legend
Percentage of Overhanging Along Bank
0 - 10%
11 - 30%
31 - 60%
61 - 80%
81 - 100%
50 0 50 100 Meters
Average Percentage of Overhanging Banks
Clark Fork River at Grant-Kohrs Ranch NHS
UTM 12. NAD 1983. HPGN (ID/MT)

Figure IV-4b

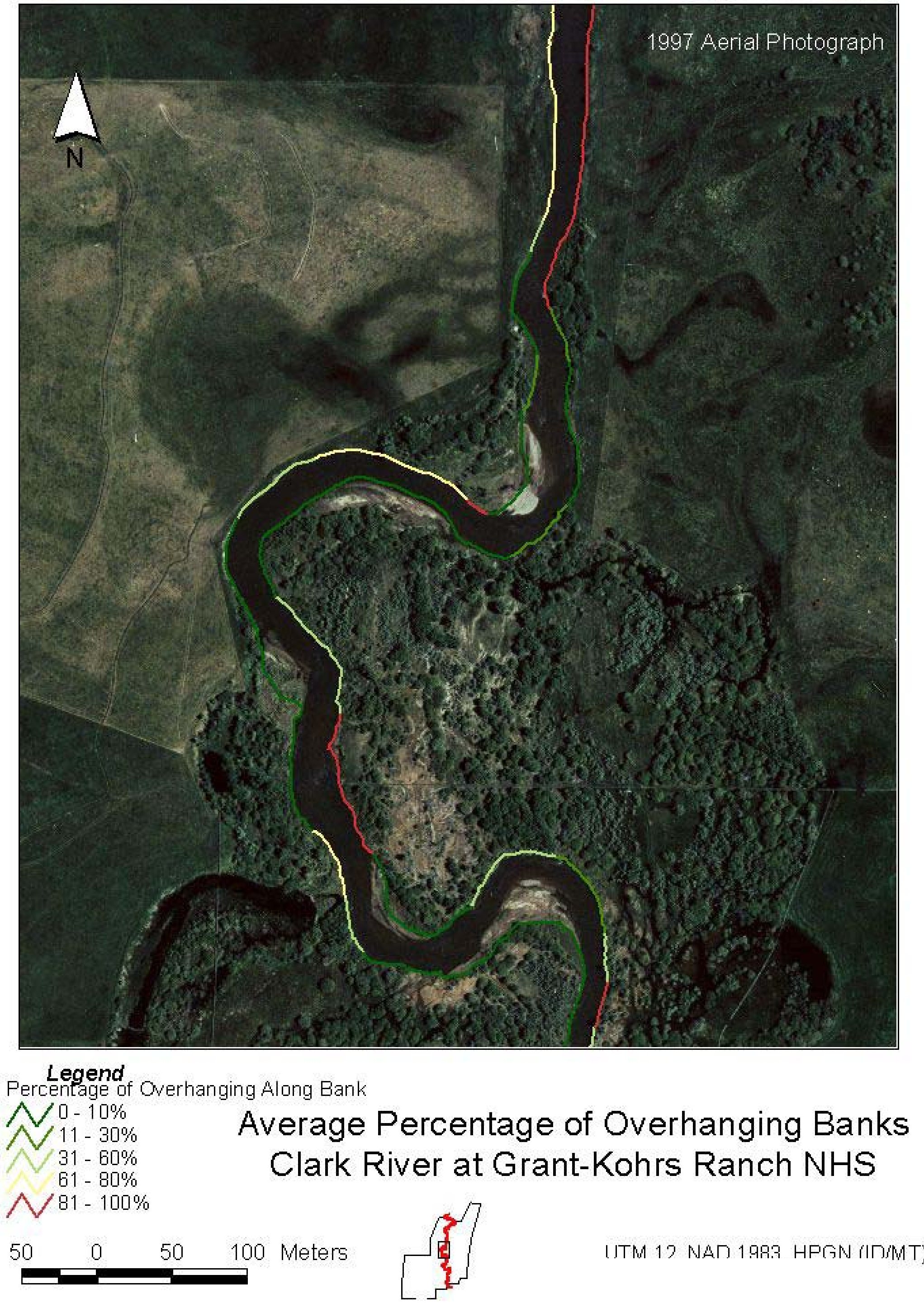

1997 Aerial Photograph
N
Legend
Percentage of Overhanging Along Bank
0 - 10%
11 - 30%
31 - 60%
61 - 80%
81 - 100%
Average Percentage of Overhanging Banks
Clark River at Grant-Kohrs Ranch NHS
50 0 50 100 Meters
UTM 12 NAD 1983 HPGN (ID/MT)

Figure IV-4c

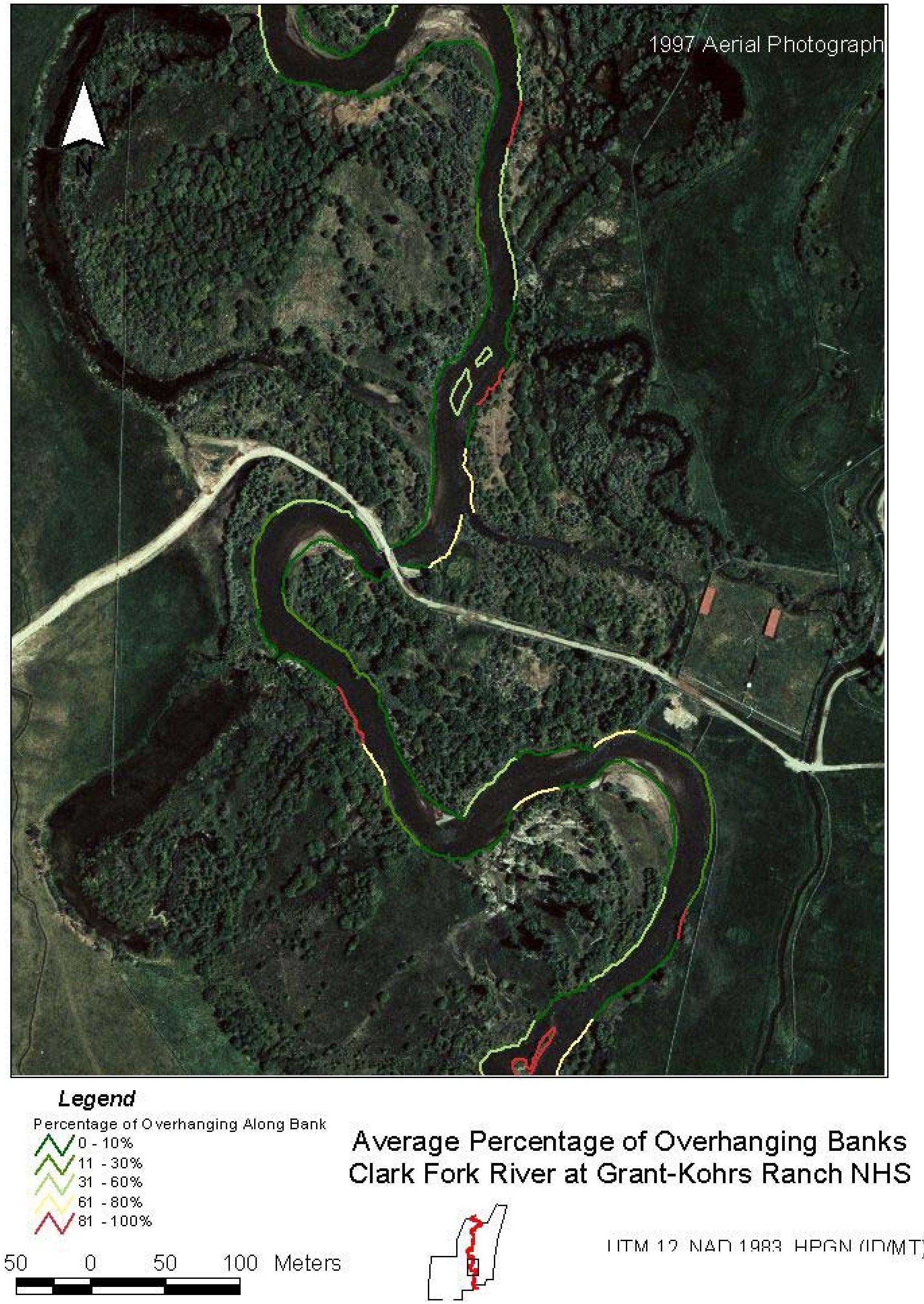

1997 Aerial Photograph
N
Legend
Percentage of Overhanging Along Bank
0 - 10%
11 - 30%
31 - 60%
61 - 80%
81 - 100%
50 0 50 100 Meters
Average Percentage of Overhanging Banks
Clark Fork River at Grant-Kohrs Ranch NHS
UTM 12, NAD 1983, HPGN (ID/MT)

Figure IV-4d

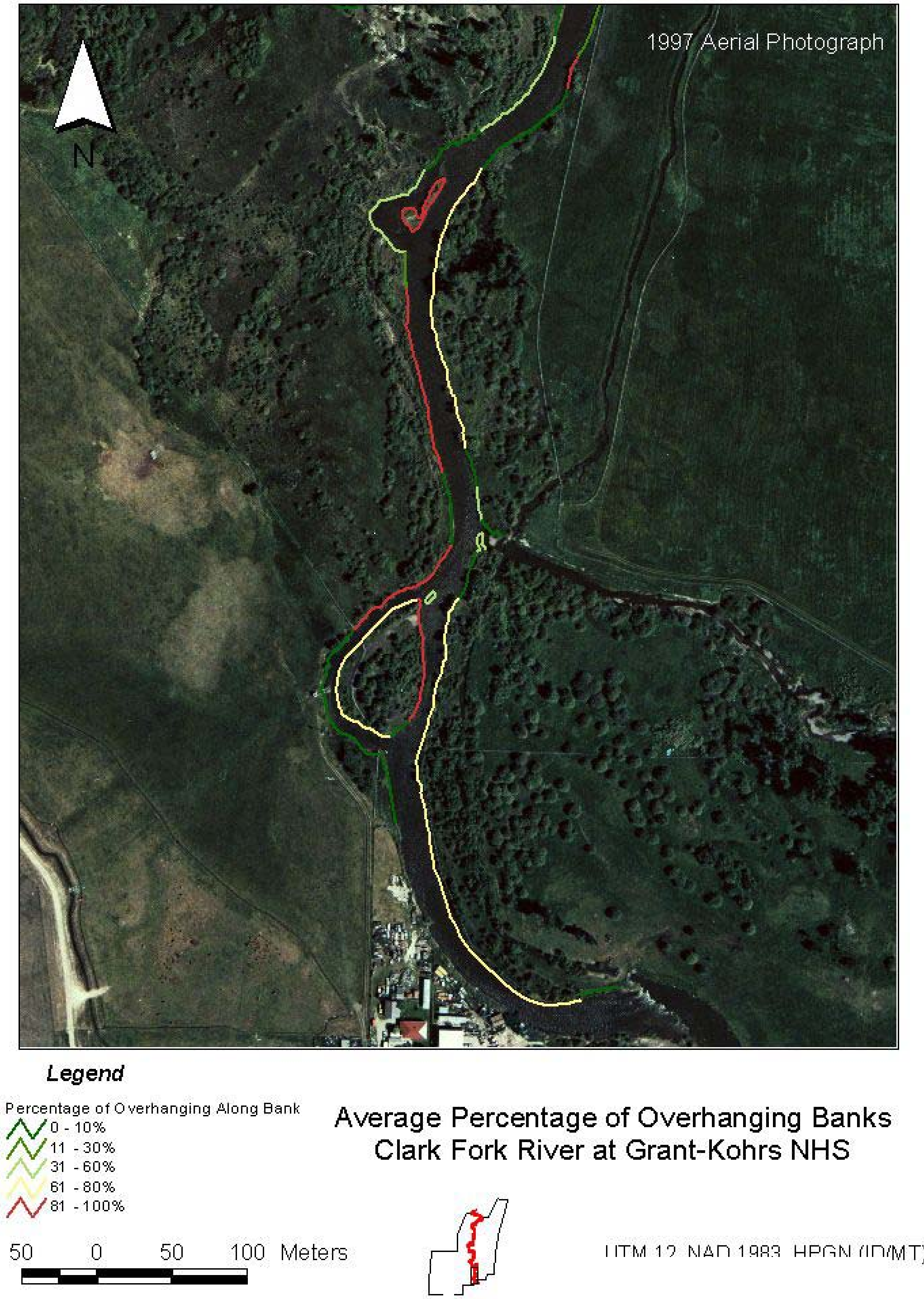

1997 Aerial Photograph
N
Legend
Percentage of Overhanging Along Bank
0 - 10%
11 - 30%
31 - 60%
61 - 80%
81 - 100%
Average Percentage of Overhanging Banks
Clark Fork River at Grant-Kohrs NHS
50 0 50 100 Meters
UTM 12 NAD 1983 HPGN (ID/MT)

Figure IV-4e

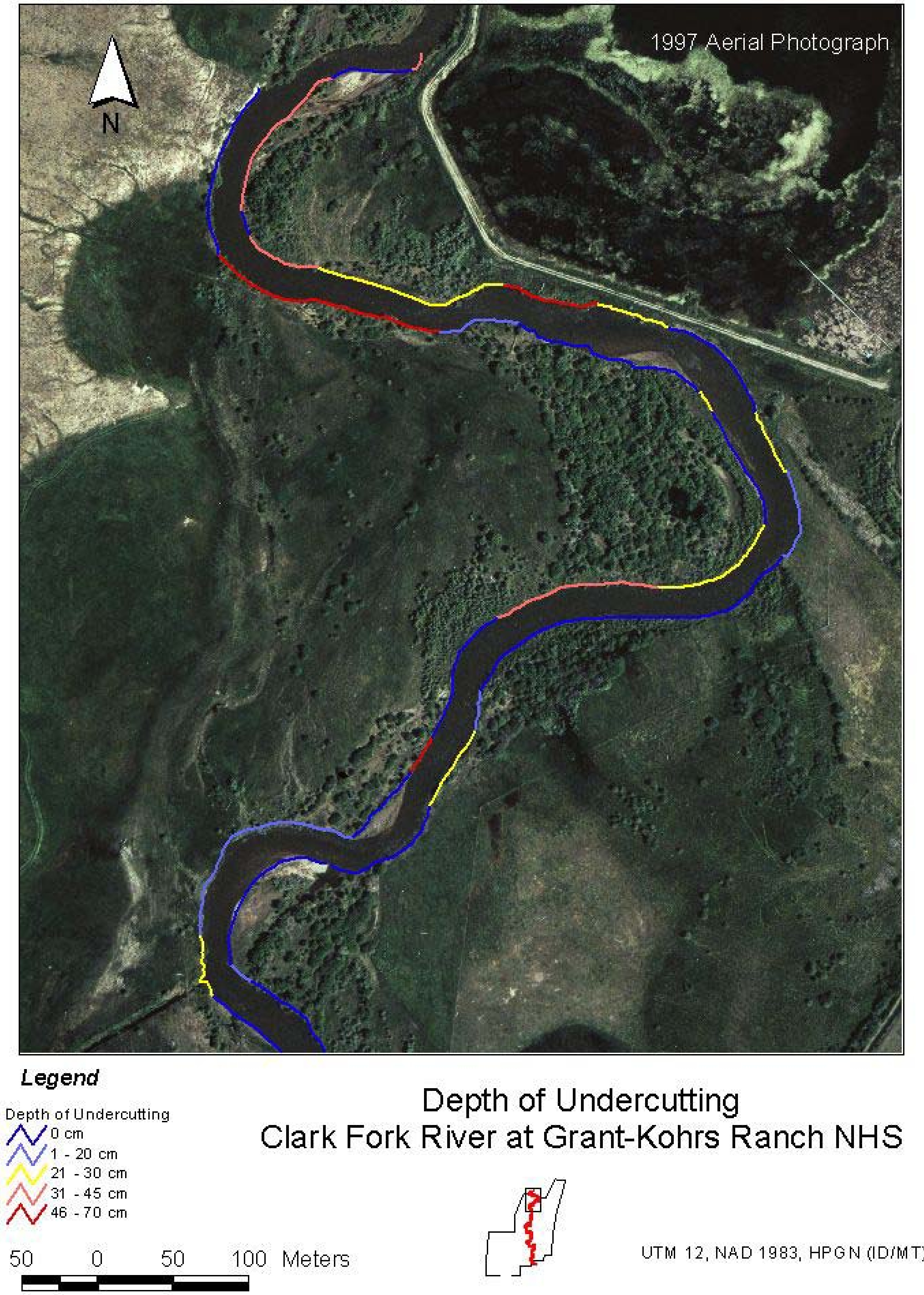

1997 Aerial Photograph
N
Legend
Depth of Undercutting
0 cm
1 - 20 cm
21 - 30 cm
31 - 45 cm
46 - 70 cm
50 0 50 100 Meters
Depth of Undercutting
Clark Fork River at Grant-Kohrs Ranch NHS
UTM 12, NAD 1983, HPGN (ID/MT)

Figure IV-5a

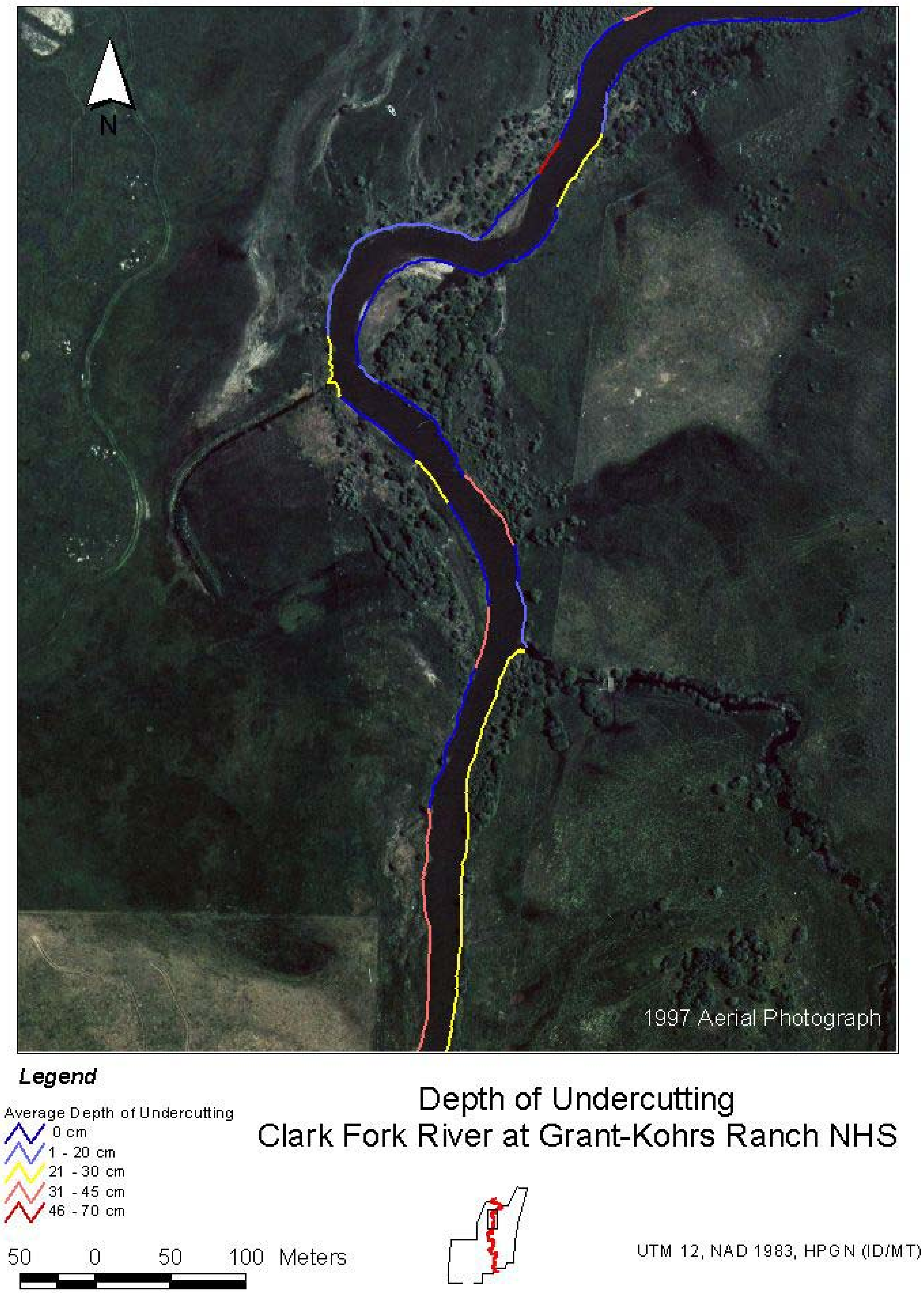

N
1997 Aerial Photograph
Legend
Average Depth of Undercutting
0 cm
1 - 20 cm
21 - 30 cm
31 - 45 cm
46 - 70 cm
50 0 50 100 Meters
Depth of Undercutting
Clark Fork River at Grant-Kohrs Ranch NHS
UTM 12, NAD 1983, HPGN (ID/MT)

Figure IV-5b

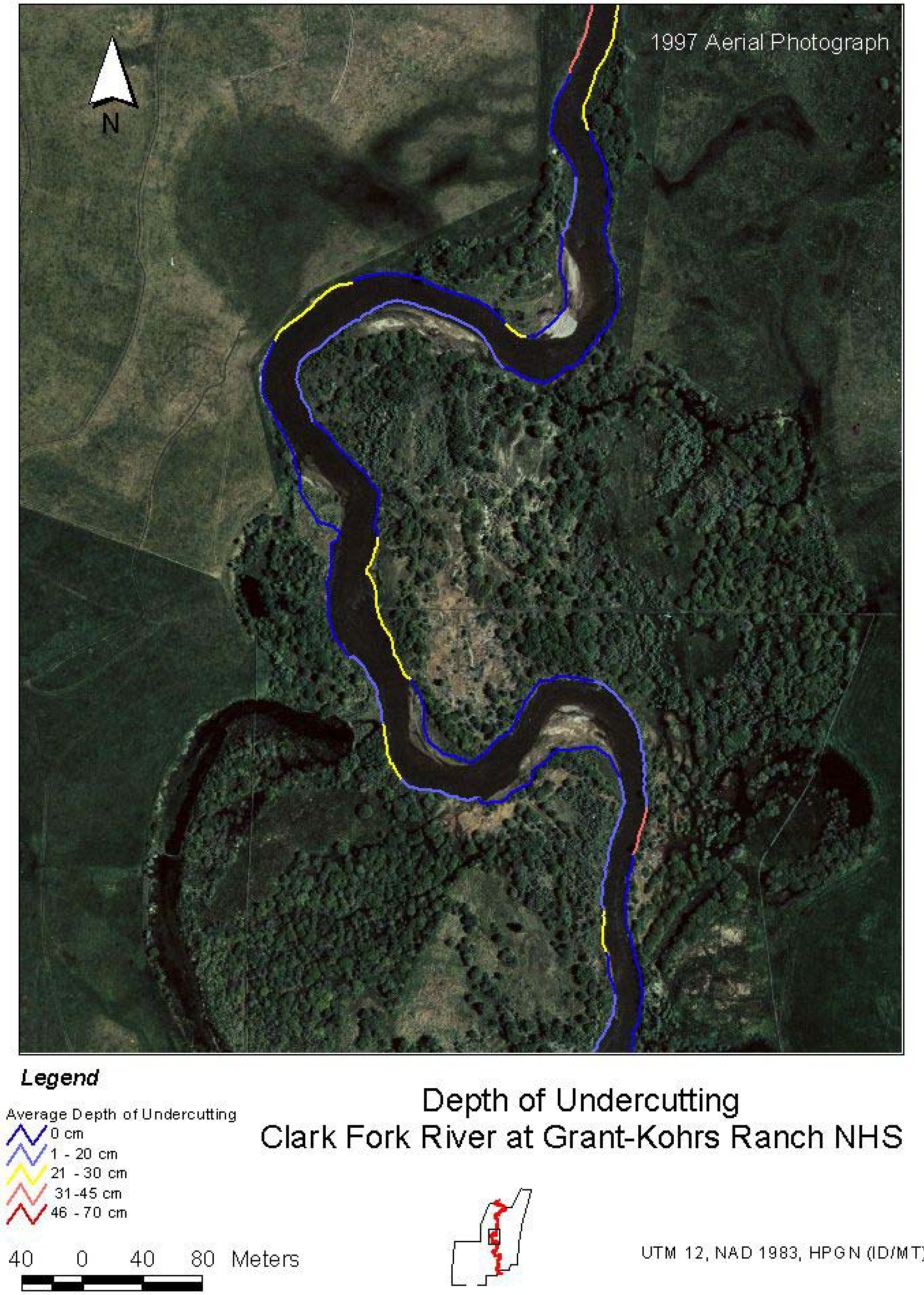

1997 Aerial Photograph
N
Legend
Average Depth of Undercutting
0 cm
1 - 20 cm
21 - 30 cm
31-45 cm
46 - 70 cm
40 0 40 80 Meters
Depth of Undercutting
Clark Fork River at Grant-Kohrs Ranch NHS
UTM 12, NAD 1983, HPGN (ID/MT)

Figure IV-5c

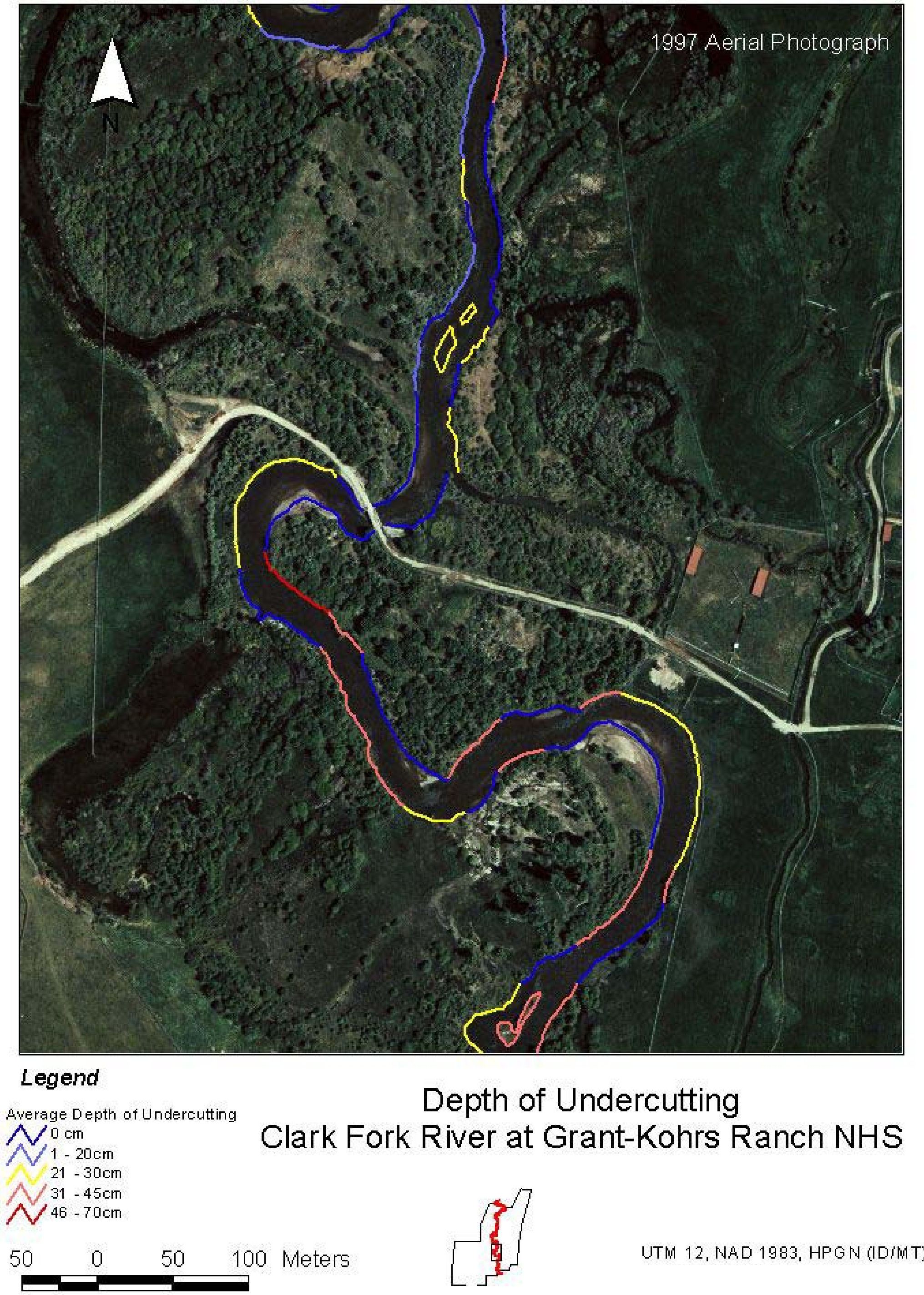

1997 Aerial Photograph
N
Legend
Average Depth of Undercutting
0 cm
1 - 20cm
21 - 30cm
31 - 45cm
46 - 70cm
50 0 50 100 Meters
Depth of Undercutting
Clark Fork River at Grant-Kohrs Ranch NHS
UTM 12, NAD 1983, HPGN (ID/MT)

Figure IV-5d

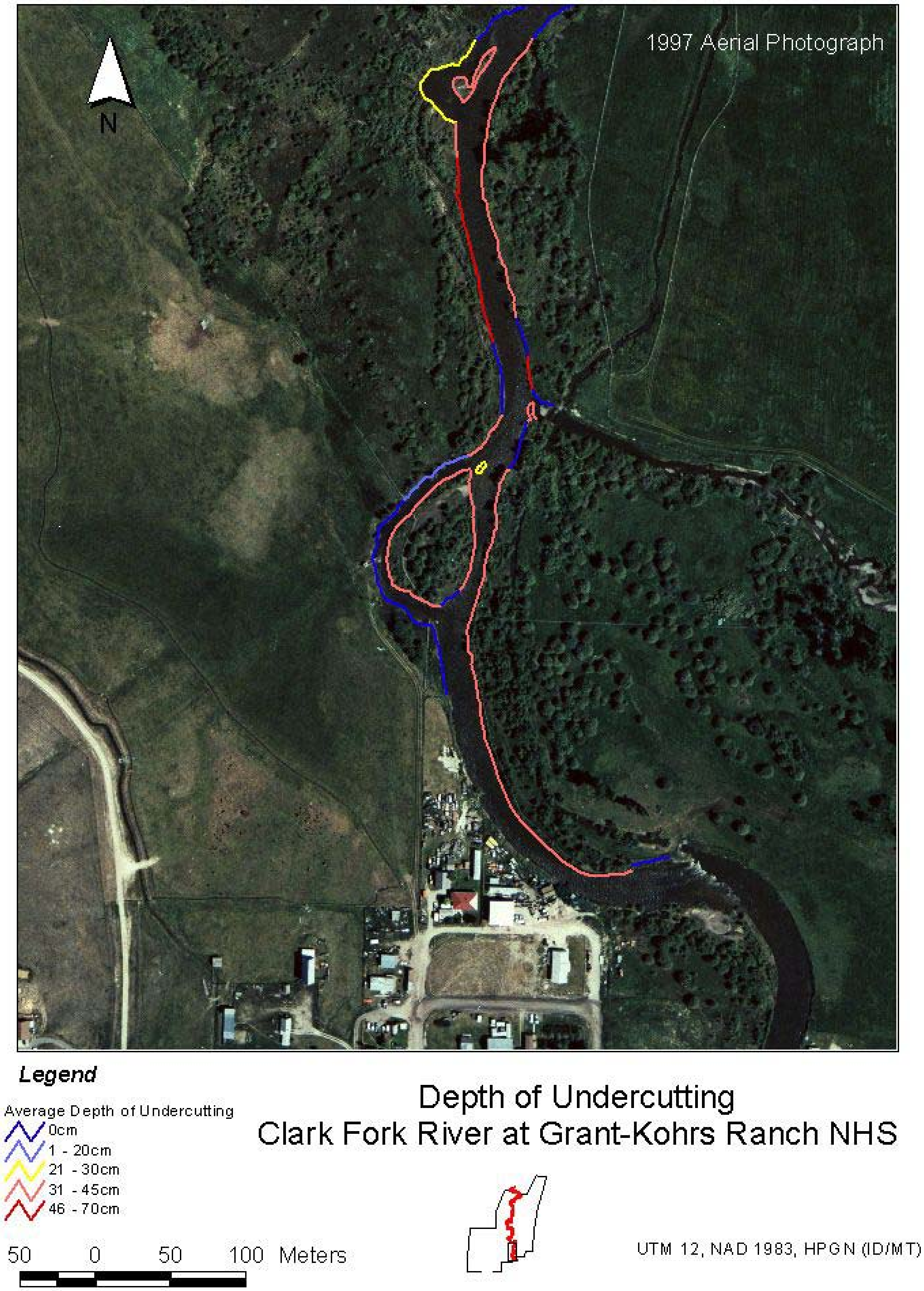

1997 Aerial Photograph
N
Legend
Average Depth of Undercutting
0cm
1 - 20cm
21 - 30cm
31 - 45cm
46 - 70cm
50 0 50 100 Meters
Depth of Undercutting
Clark Fork River at Grant-Kohrs Ranch NHS
UTM 12, NAD 1983, HPGN (ID/MT)

Figure IV-5e

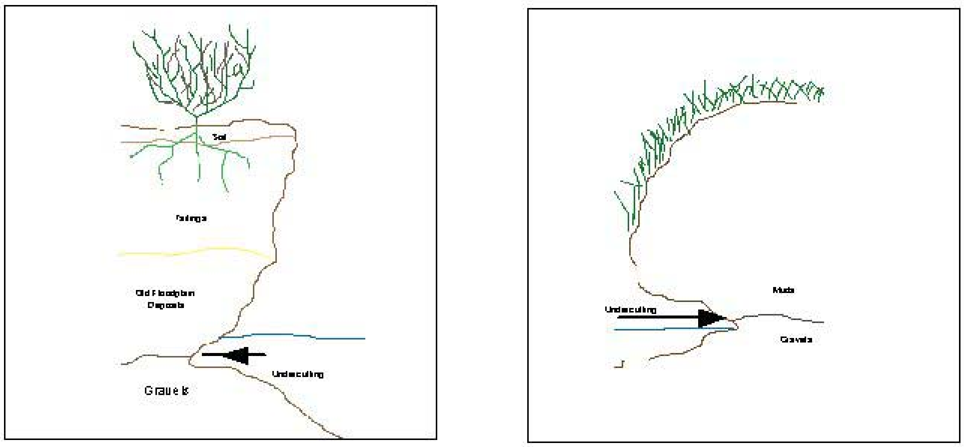


Figure IV-6.   Examples of Overhanging Banks

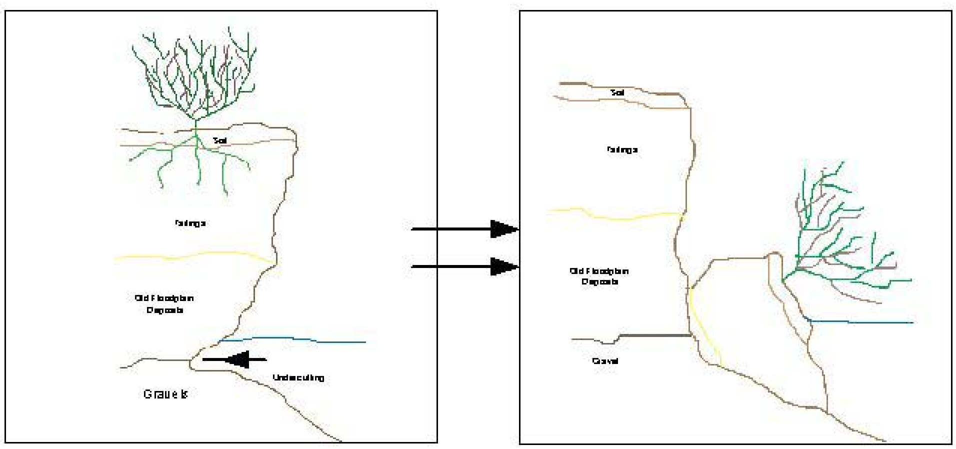


Figure IV-7. Slumping Process. River undercuts Banks until Bank Fails and the Upper Portion of the Bank Falls Into the River

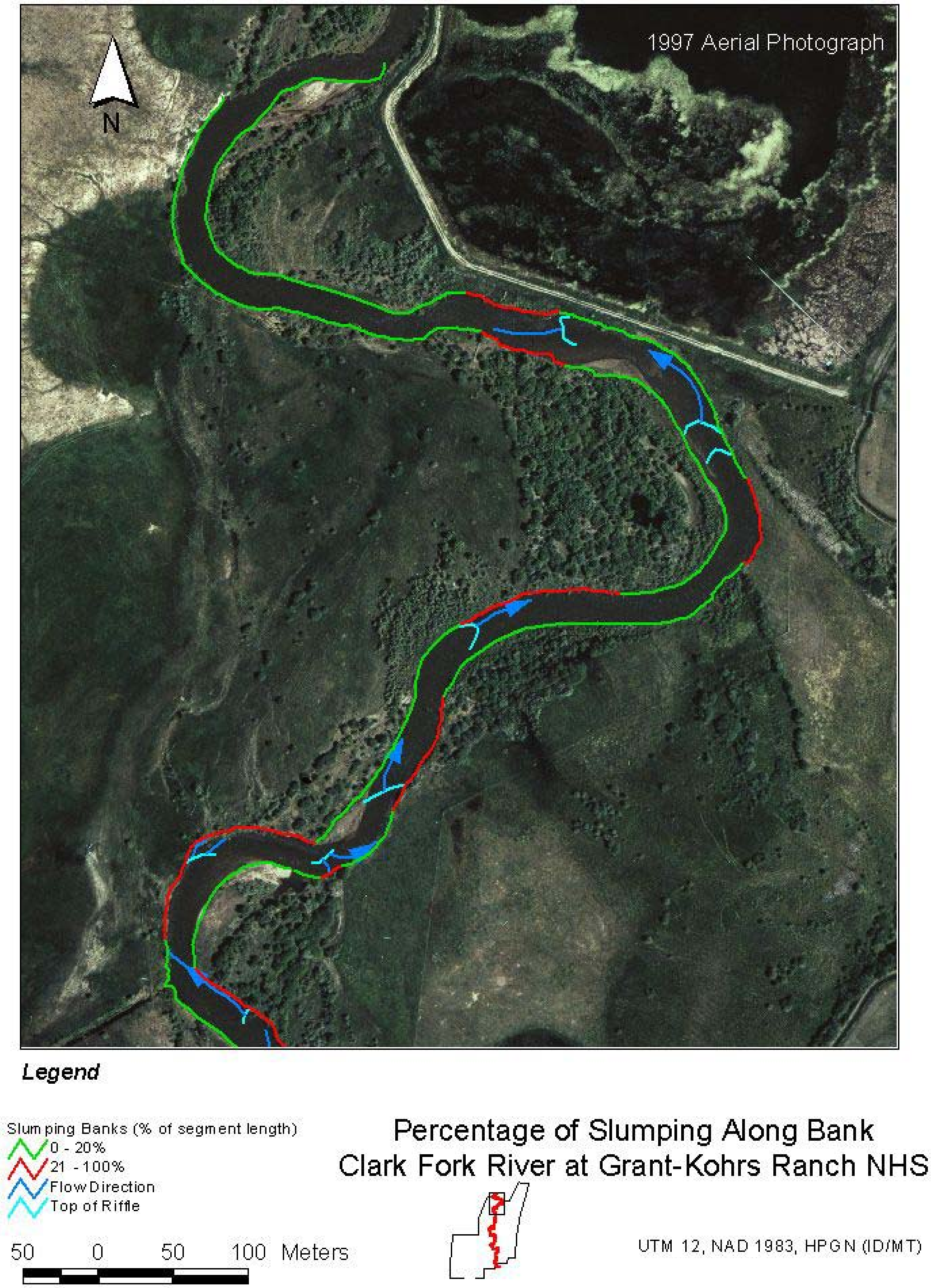

1997 Aerial Photograph
N
Legend
Slumping Banks (% of segment length)
0 - 20%
21 - 100%
Flow Direction
Top of Riffle
50 0 50 100 Meters
Percentage of Slumping Along Bank
Clark Fork River at Grant-Kohrs Ranch NHS
UTM 12, NAD 1983, HPGN (ID/MT)

Figure IV-8a

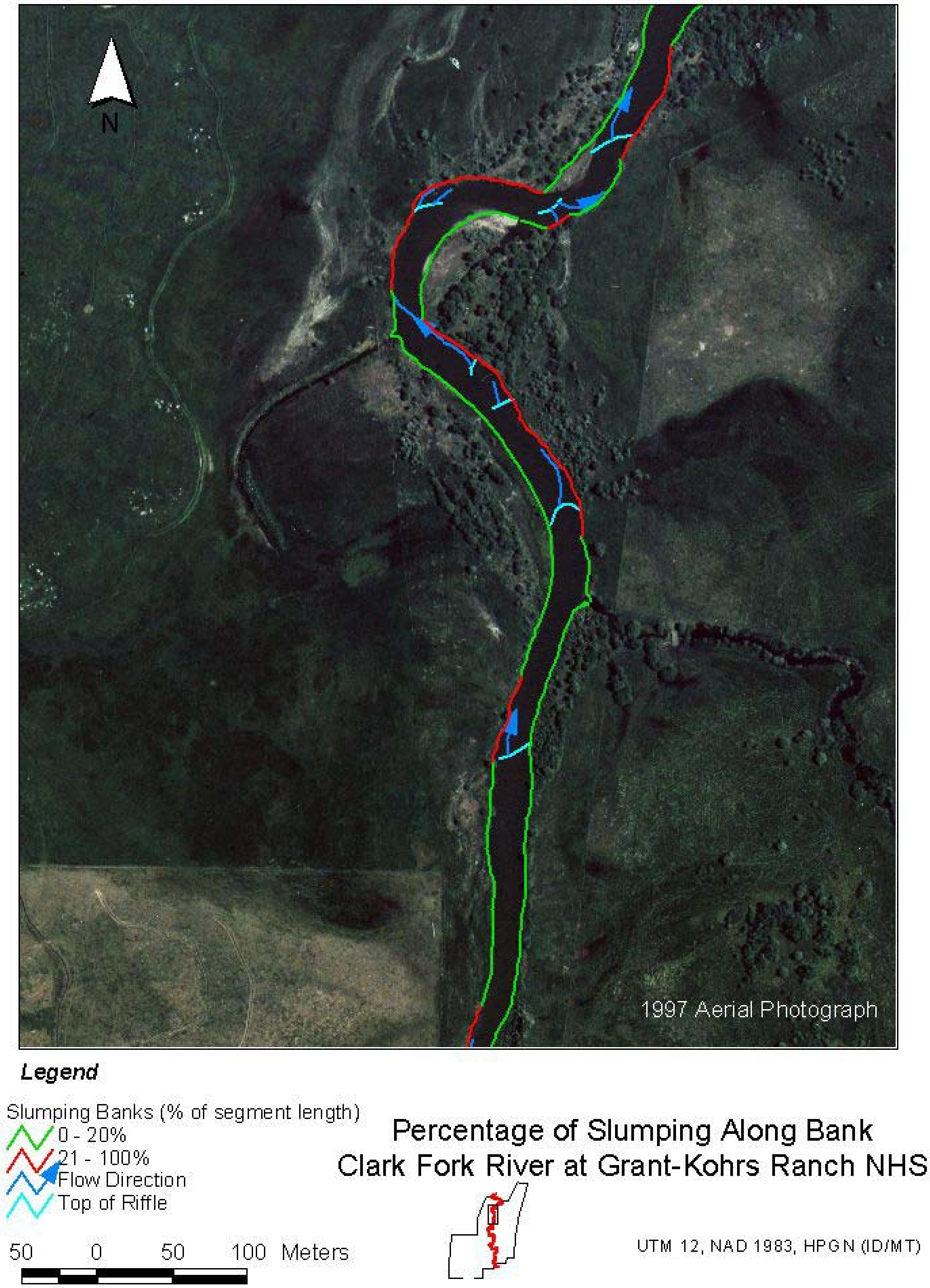
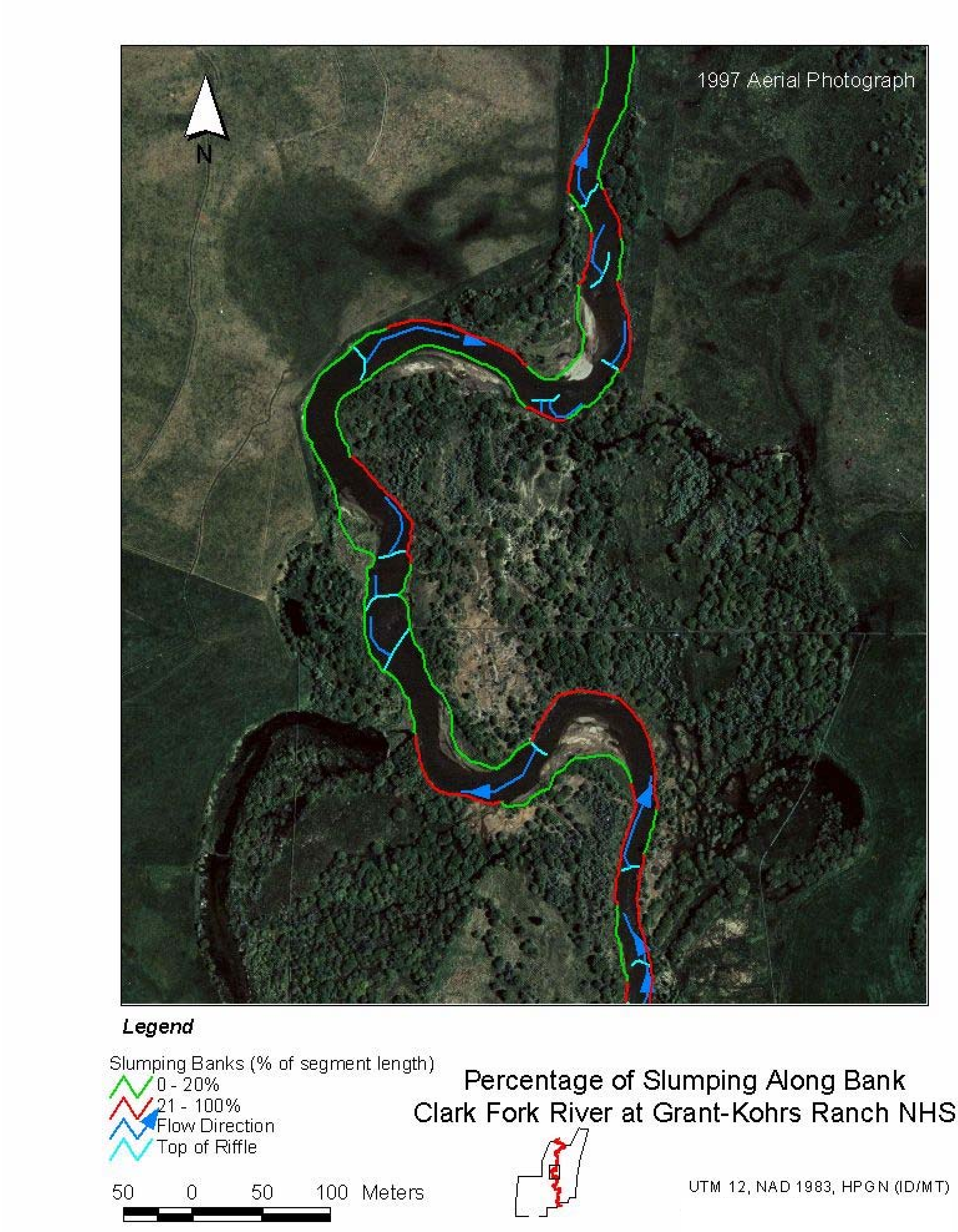

N
1997 Aerial Photograph
Legend
Slumping Banks (% of segment length)
0 - 20%
21 - 100%
Flow Direction
Top of Riffle
50 0 50 100 Meters
Percentage of Slumping Along Bank
Clark Fork River at Grant-Kohrs Ranch NHS
UTM 12, NAD 1983, HPGN (ID/MT)

Figure IV-8b



1997 Aerial Photograph
N
Legend
Slumping Banks (% of segment length)
0 - 20%
21 - 100%
Flow Direction
Top of Riffle
50 0 50 100 Meters
Percentage of Slumping Along Bank
Clark Fork River at Grant-Kohrs Ranch NHS
UTM 12, NAD 1983, HPGN (ID/MT)

Figure IV-8c

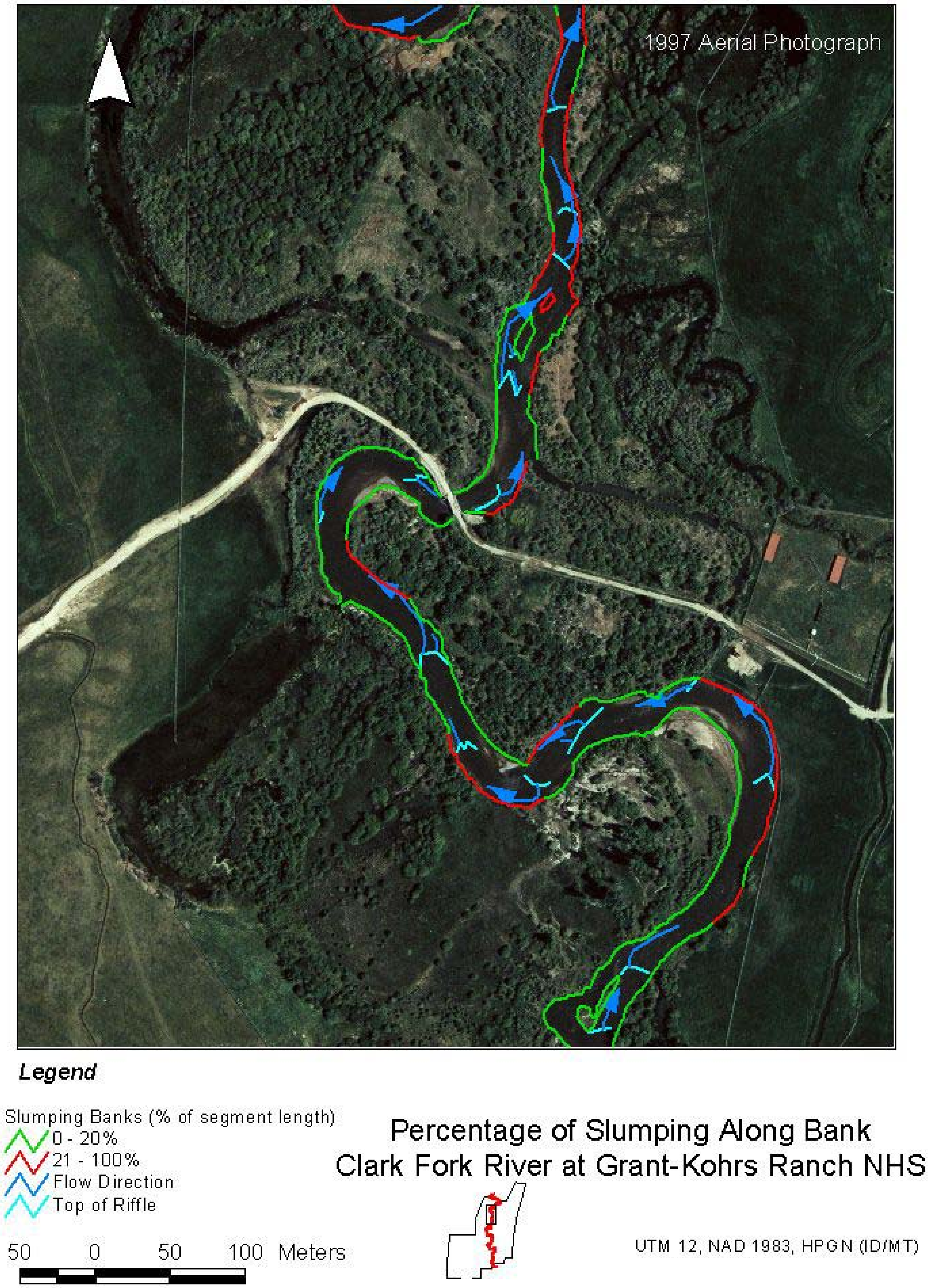

1997 Aerial Photograph
N
Legend
Slumping Banks (% of segment length)
0 - 20%
21 - 100%
Flow Direction
Top of Riffle
50 0 50 100 Meters
Percentage of Slumping Along Bank
Clark Fork River at Grant-Kohrs Ranch NHS
UTM 12, NAD 1983, HPGN (ID/MT)

Figure IV-8d

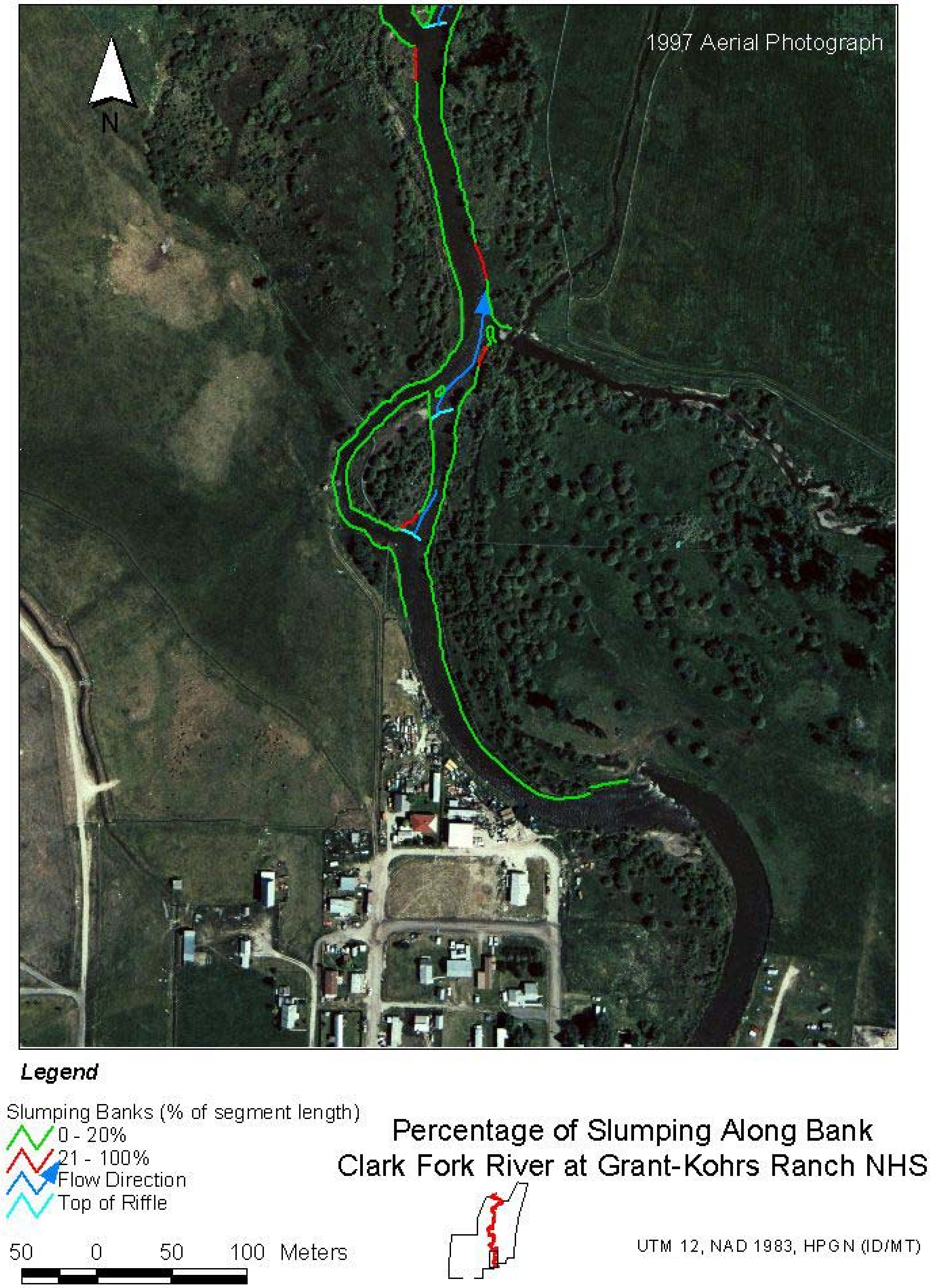

1997 Aerial Photograph
N
Legend
Slumping Banks (% of segment length)
0 - 20%
21 - 100%
Flow Direction
Top of Riffle
50 0 50 100 Meters
Percentage of Slumping Along Bank
Clark Fork River at Grant-Kohrs Ranch NHS
UTM 12, NAD 1983, HPGN (ID/MT)

Figure IV-8e

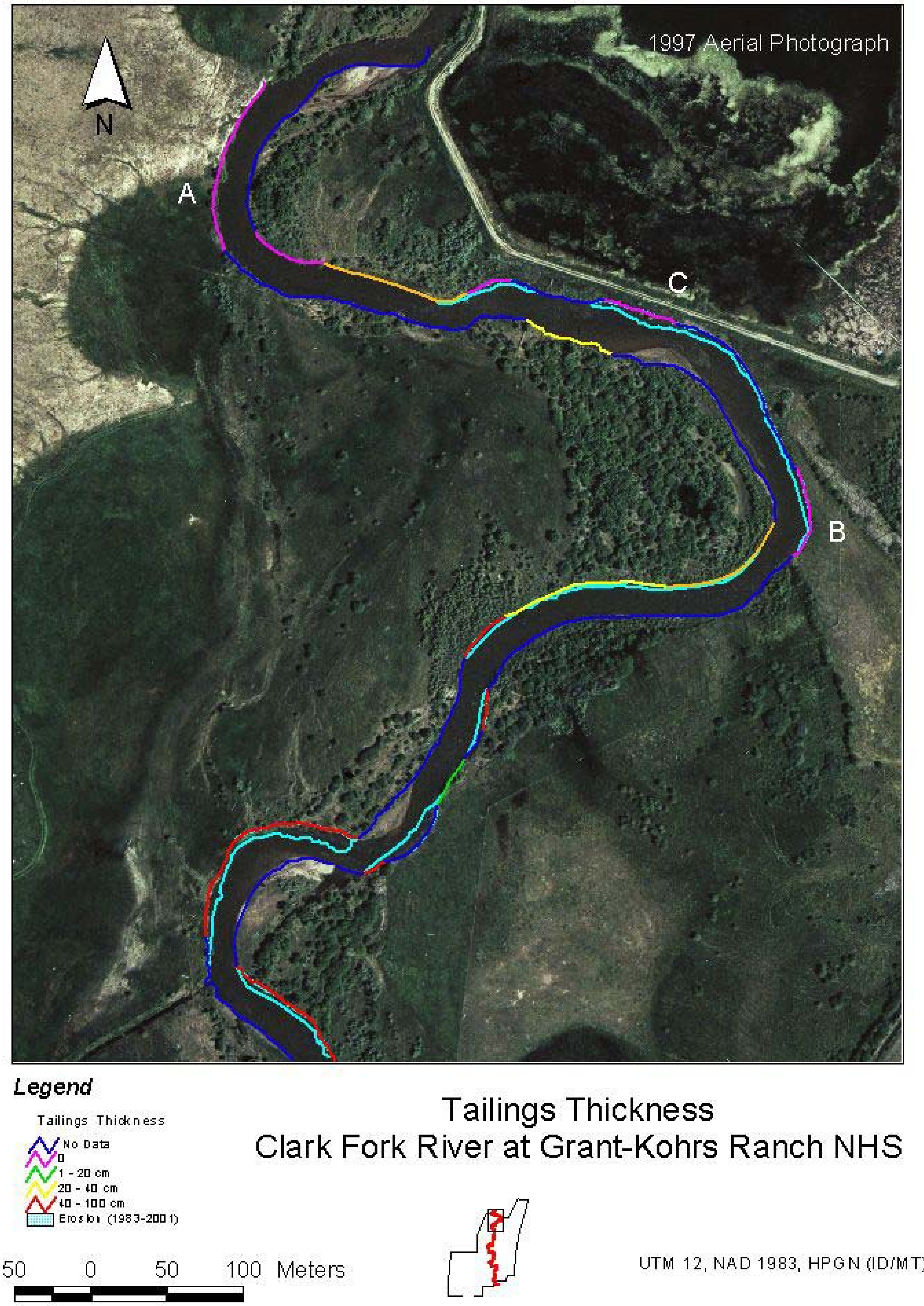

1997 Aerial Photograph
N
A
B
C
Legend
Tailings Thickness
No Data
0
1 - 20 cm
20 - 40 cm
40 - 100 cm
Erosion (1983-2001)
Tailings Thickness
Clark Fork River at Grant-Kohrs Ranch NHS
50 0 50 100 Meters
UTM 12, NAD 1983, HPGN (ID/MT)

Figure IV-9a

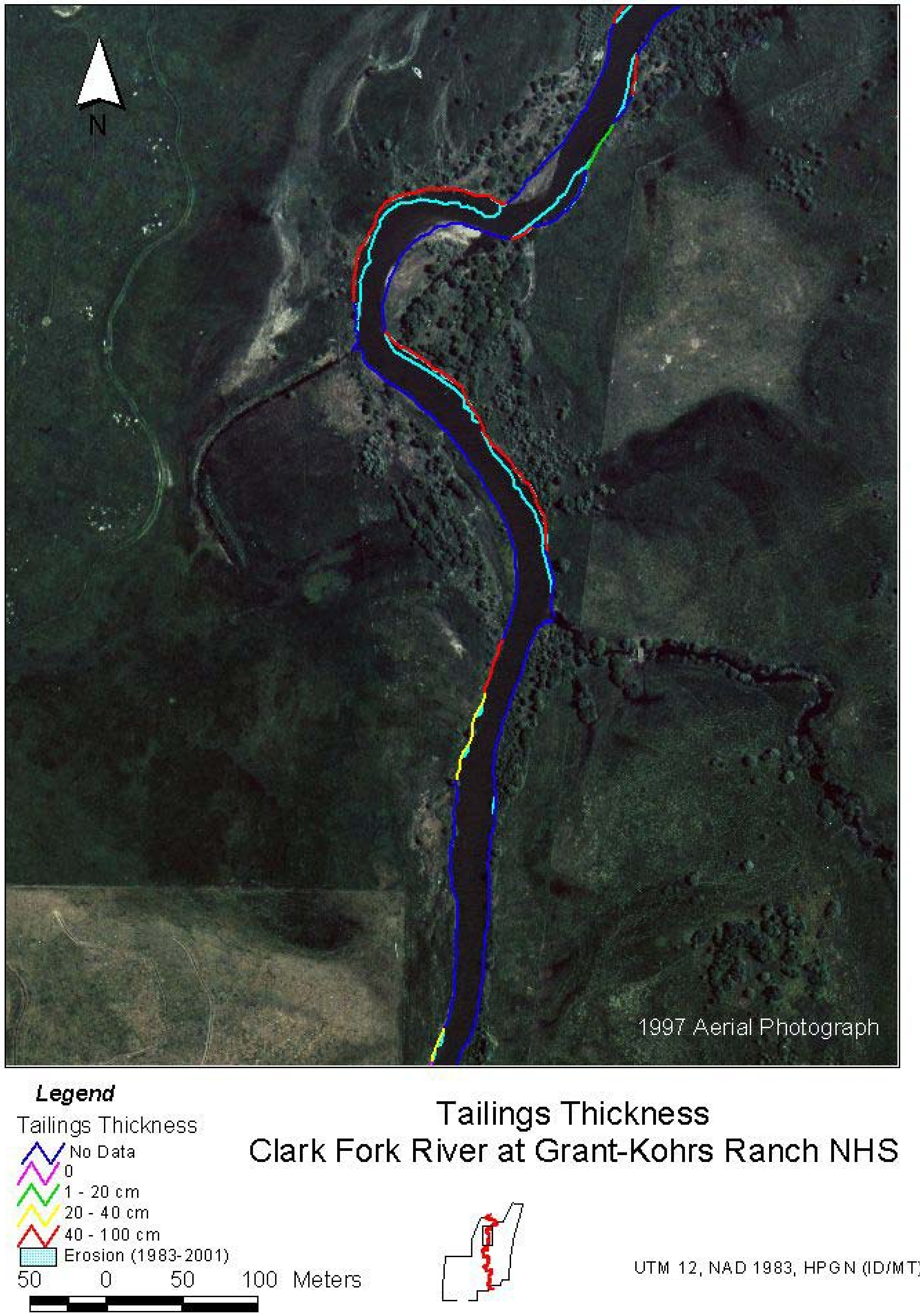
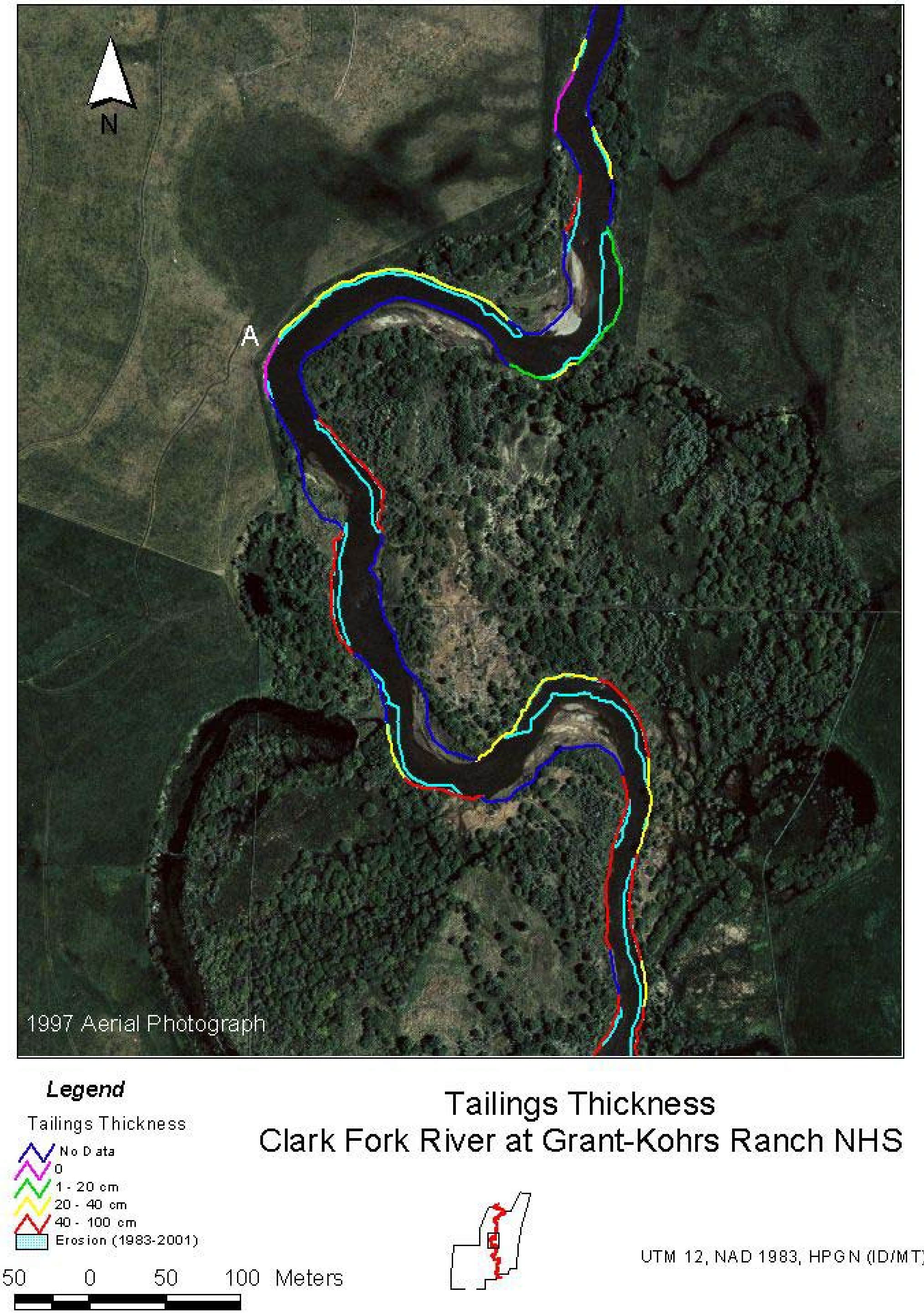

N
1997 Aerial Photograph
Legend
Tailings Thickness
No Data
0
1 - 20 cm
20 - 40 cm
40 - 100 cm
Erosion (1983-2001)
50 0 50 100 Meters
Tailings Thickness
Clark Fork River at Grant-Kohrs Ranch NHS
UTM 12, NAD 1983, HPGN (ID/MT)

Figure IV-9b


N
A
1997 Aerial Photograph
Legend
Tailings Thickness
No Data
0
1 - 20 cm
20 - 40 cm
40 - 100 cm
Erosion (1983-2001)
50 0 50 100 Meters
Tailings Thickness
Clark Fork River at Grant-Kohrs Ranch NHS
UTM 12, NAD 1983, HPGN (ID/MT)

Figue IV-9c

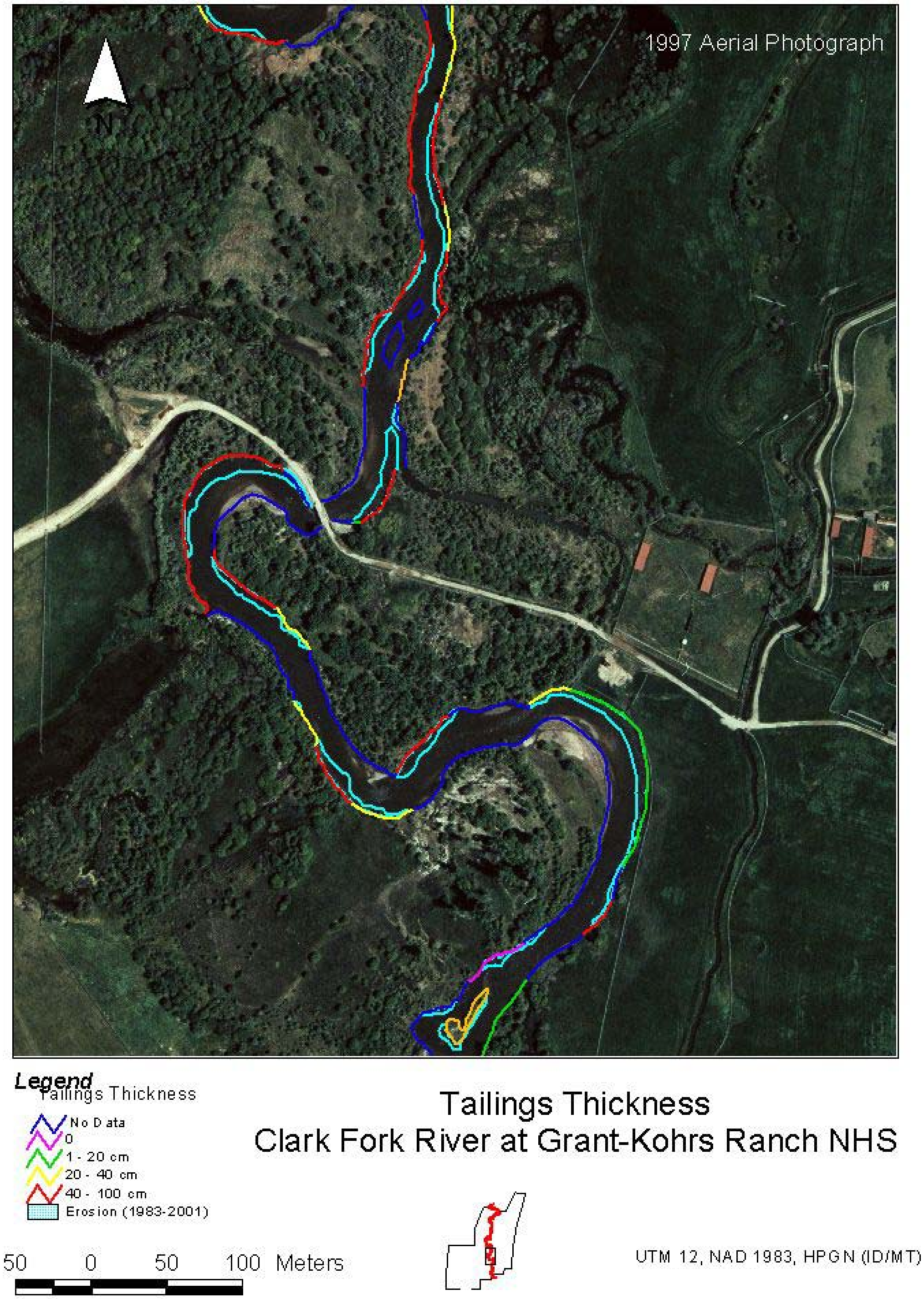

1997 Aerial Photograph
N
Legend
Tailings Thickness
No Data
0
1 - 20 cm
20 - 40 cm
40 - 100 cm
Erosion (1983-2001)
Tailings Thickness
Clark Fork River at Grant-Kohrs Ranch NHS
50 0 50 100 Meters
UTM 12, NAD 1983, HPGN (ID/MT)

Figure IV-9d

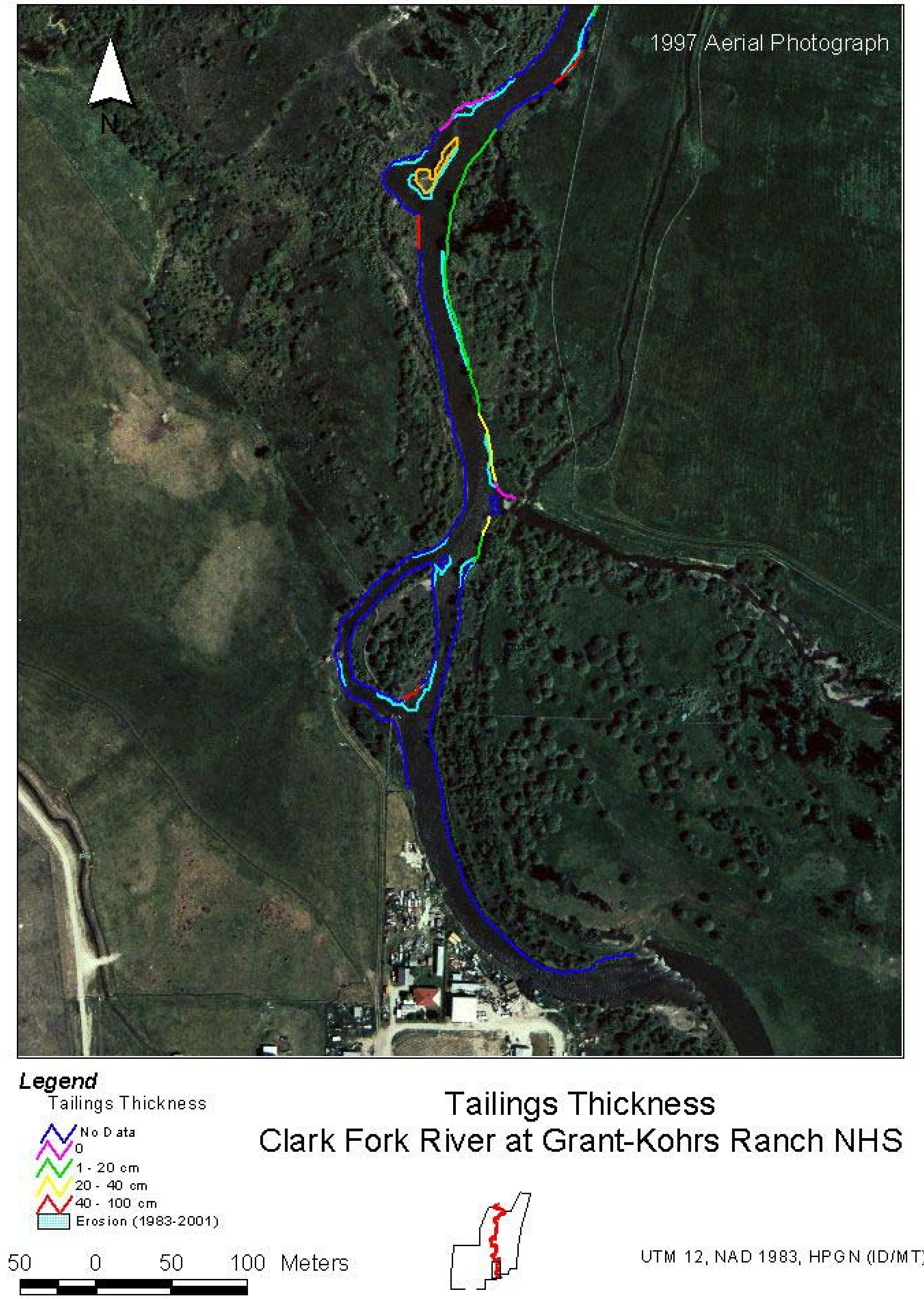

1997 Aerial Photograph
N
Legend
Tailings Thickness
No Data
0
1 - 20 cm
20 - 40 cm
40 - 100 cm
Erosion (1983-2001)
50 0 50 100 Meters
Tailings Thickness
Clark Fork River at Grant-Kohrs Ranch NHS
UTM 12, NAD 1983, HPGN (ID/MT)

Figure IV-9e

Figure IV-10

Slumping Banks
(Stuart Field)

Salts formed on Convex Bank

Figure IV-11

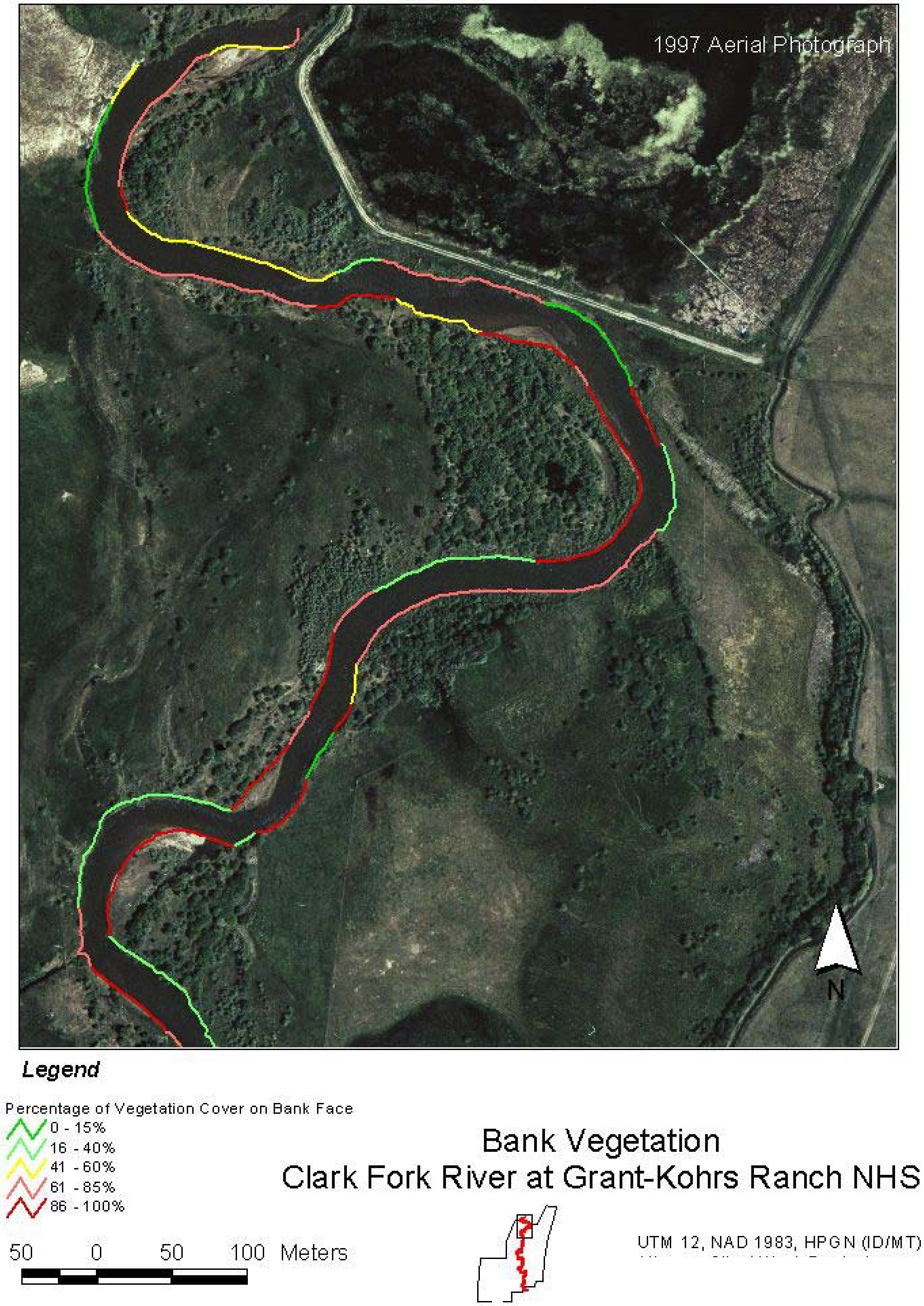


Figure IV-12a

Figure IV-12b

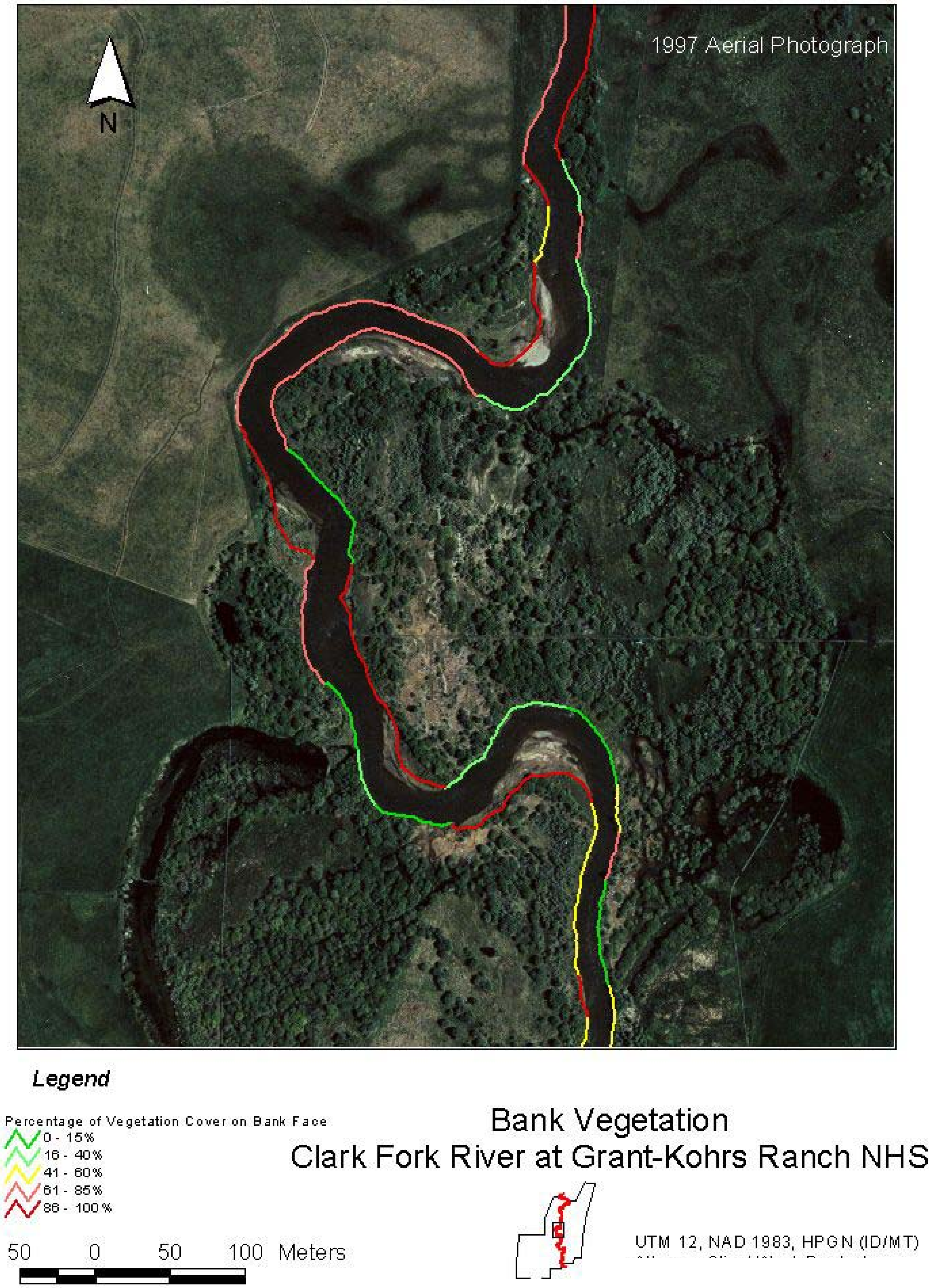


Figure IV-12c

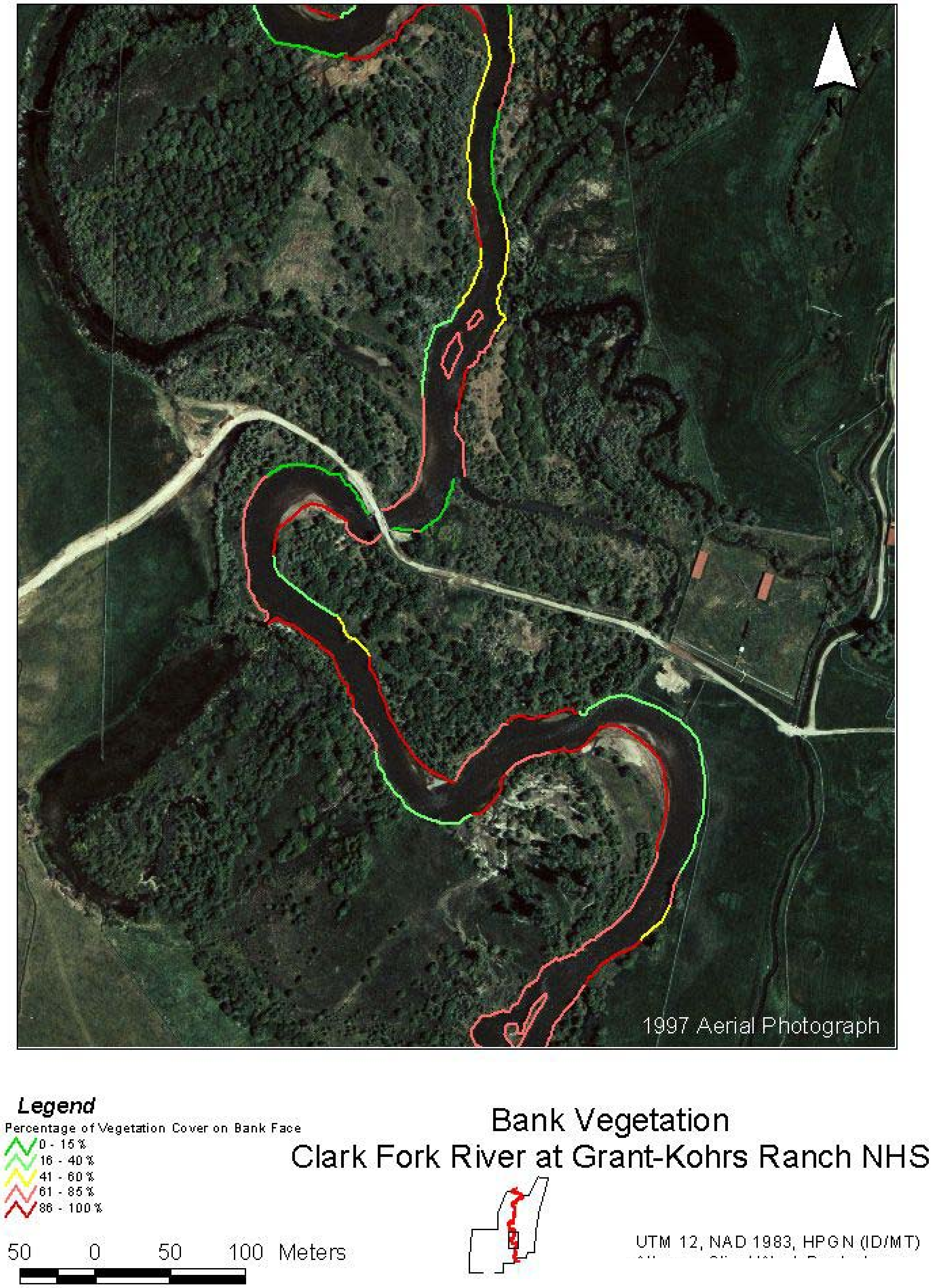


Figure IV-12d

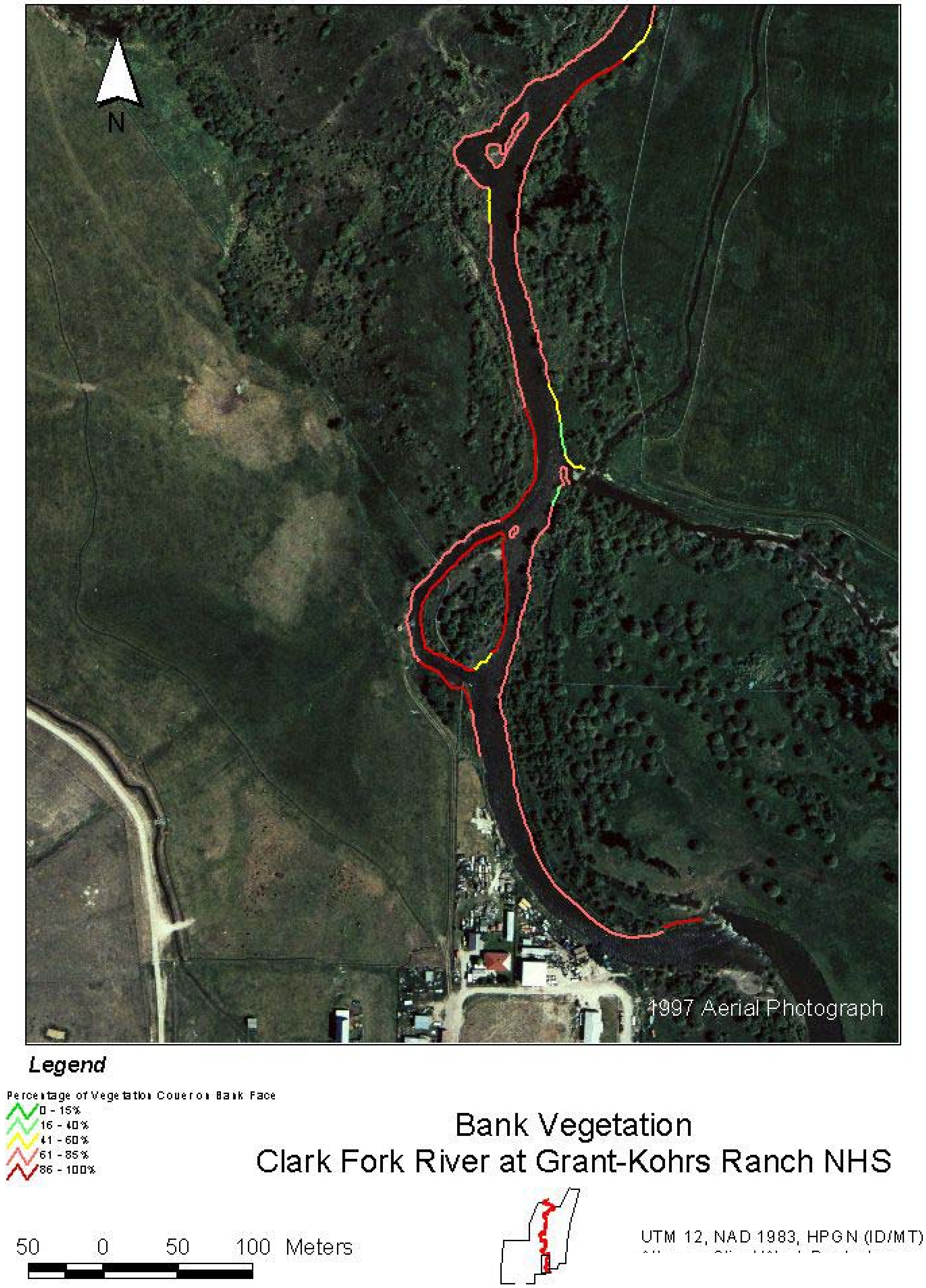


Figure IV-12e

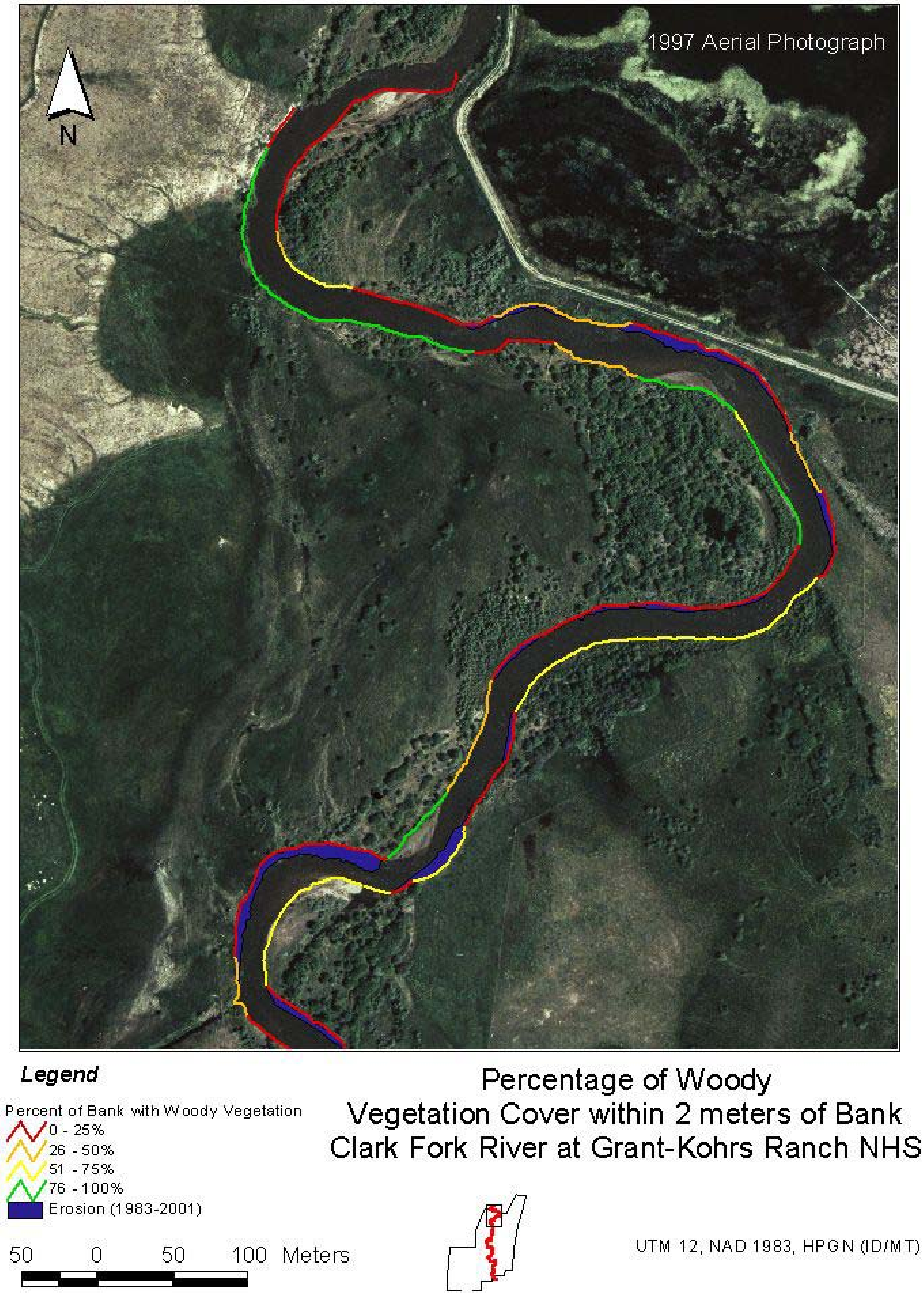


Figure IV-13a

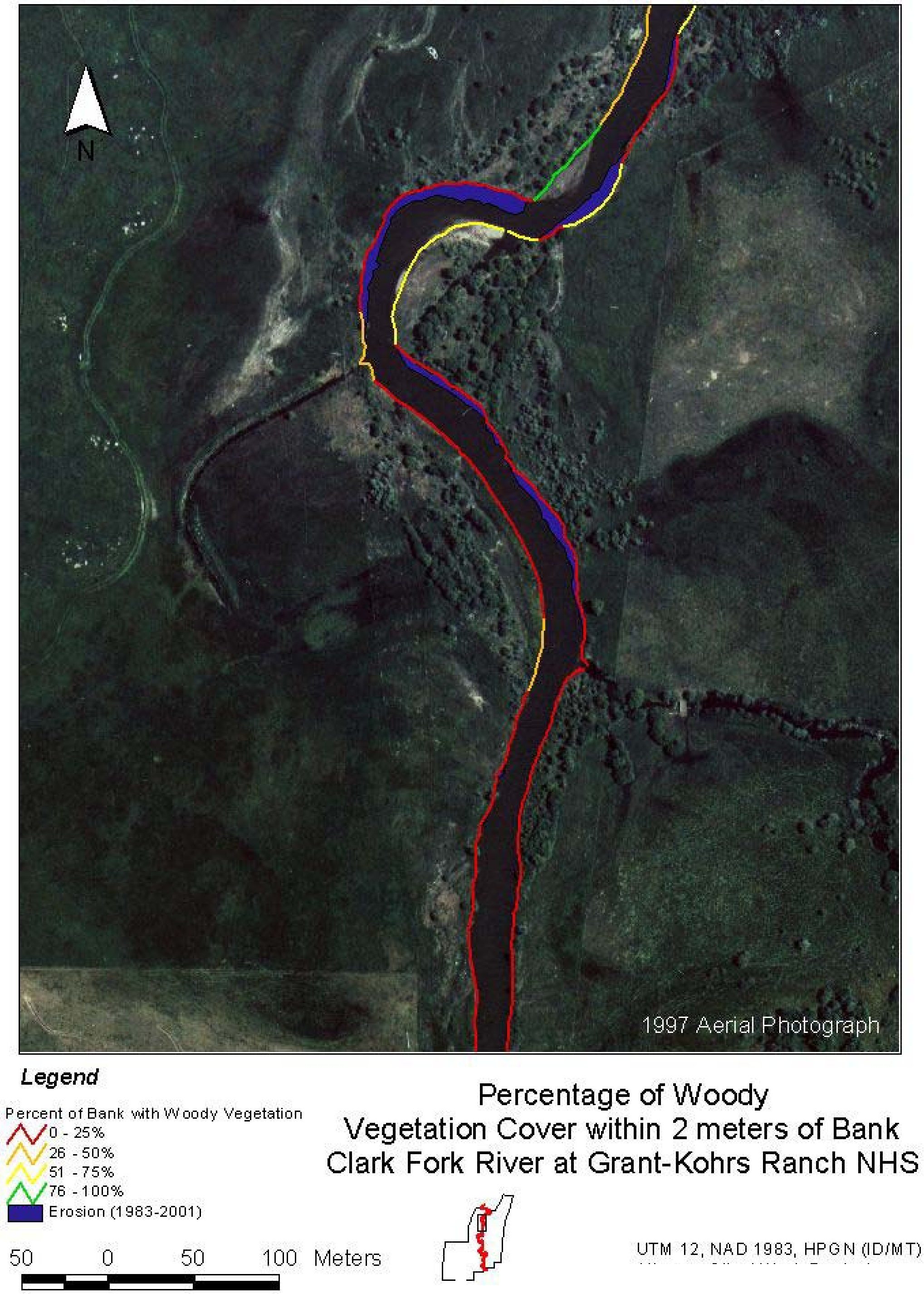


Figure IV-13b

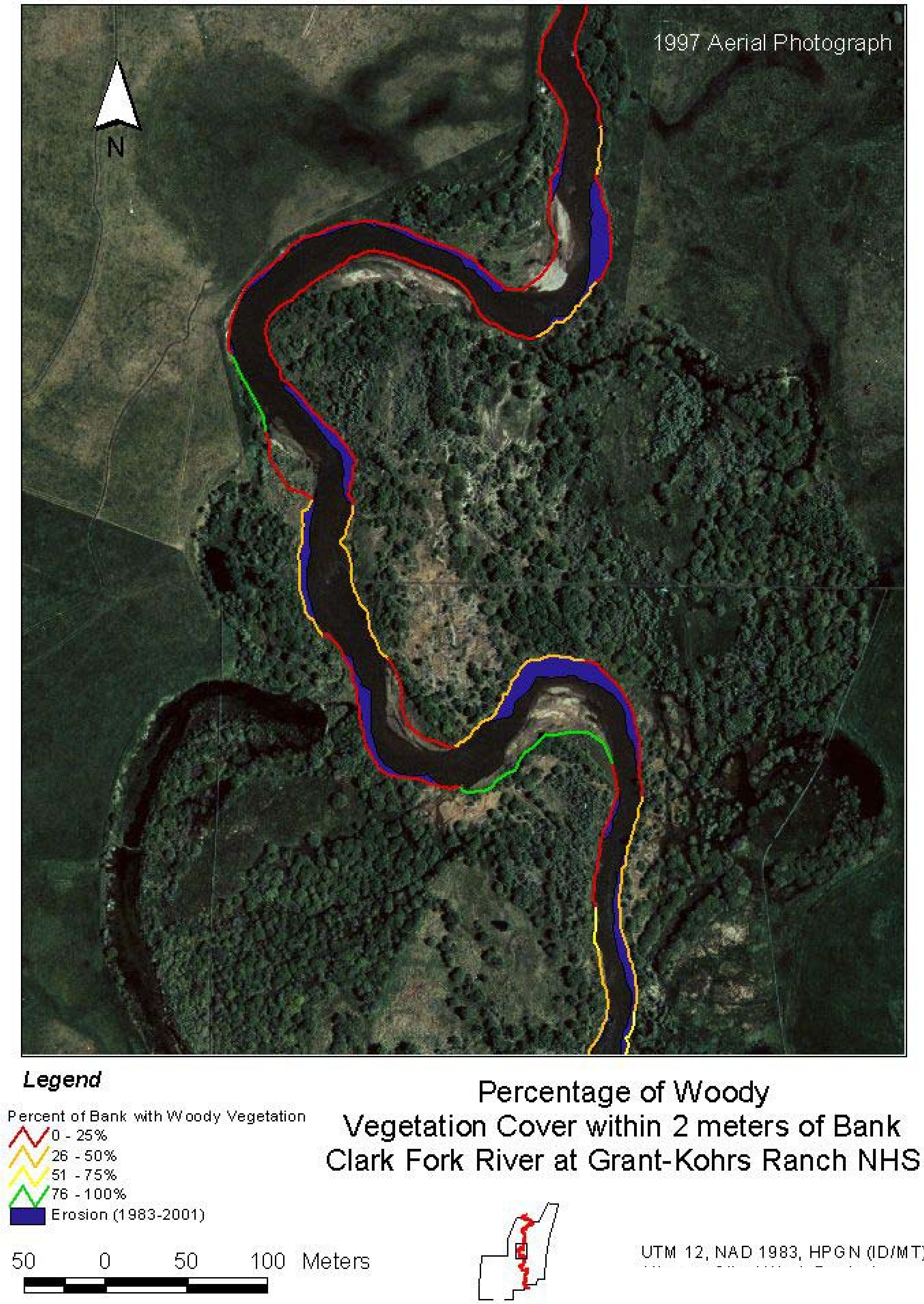


Figure IV-13c

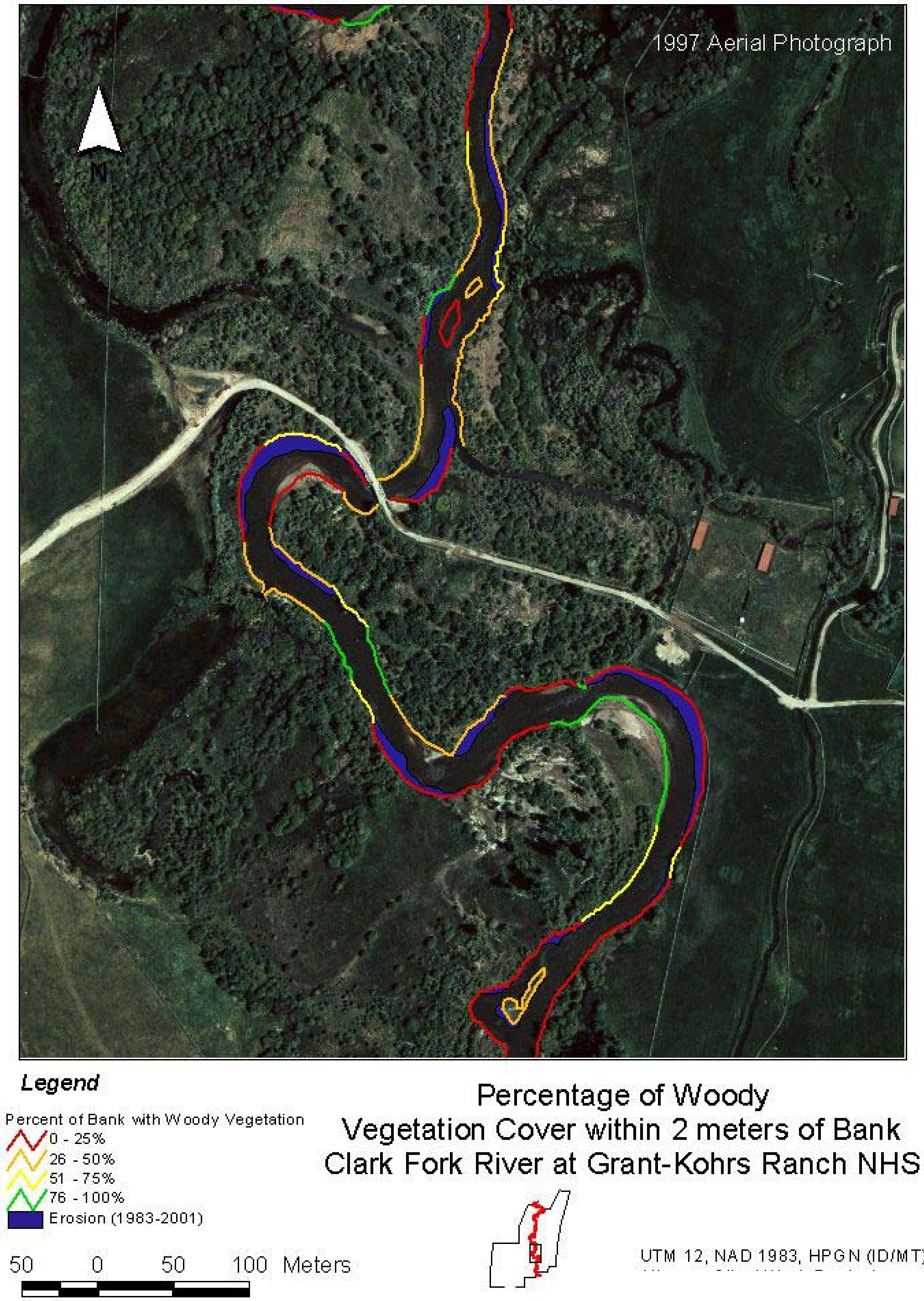


Figure IV-13d

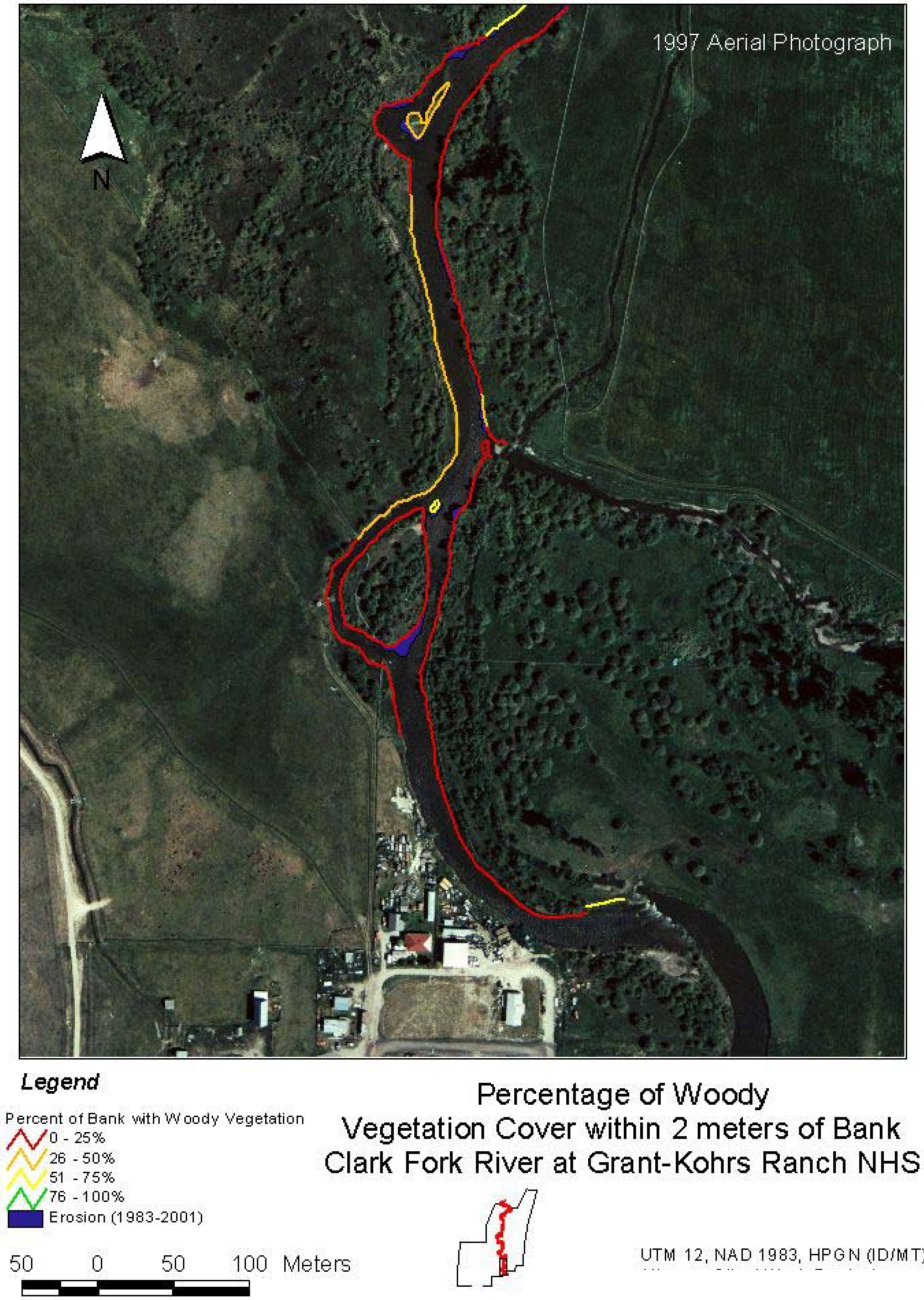


Figure IV-13e

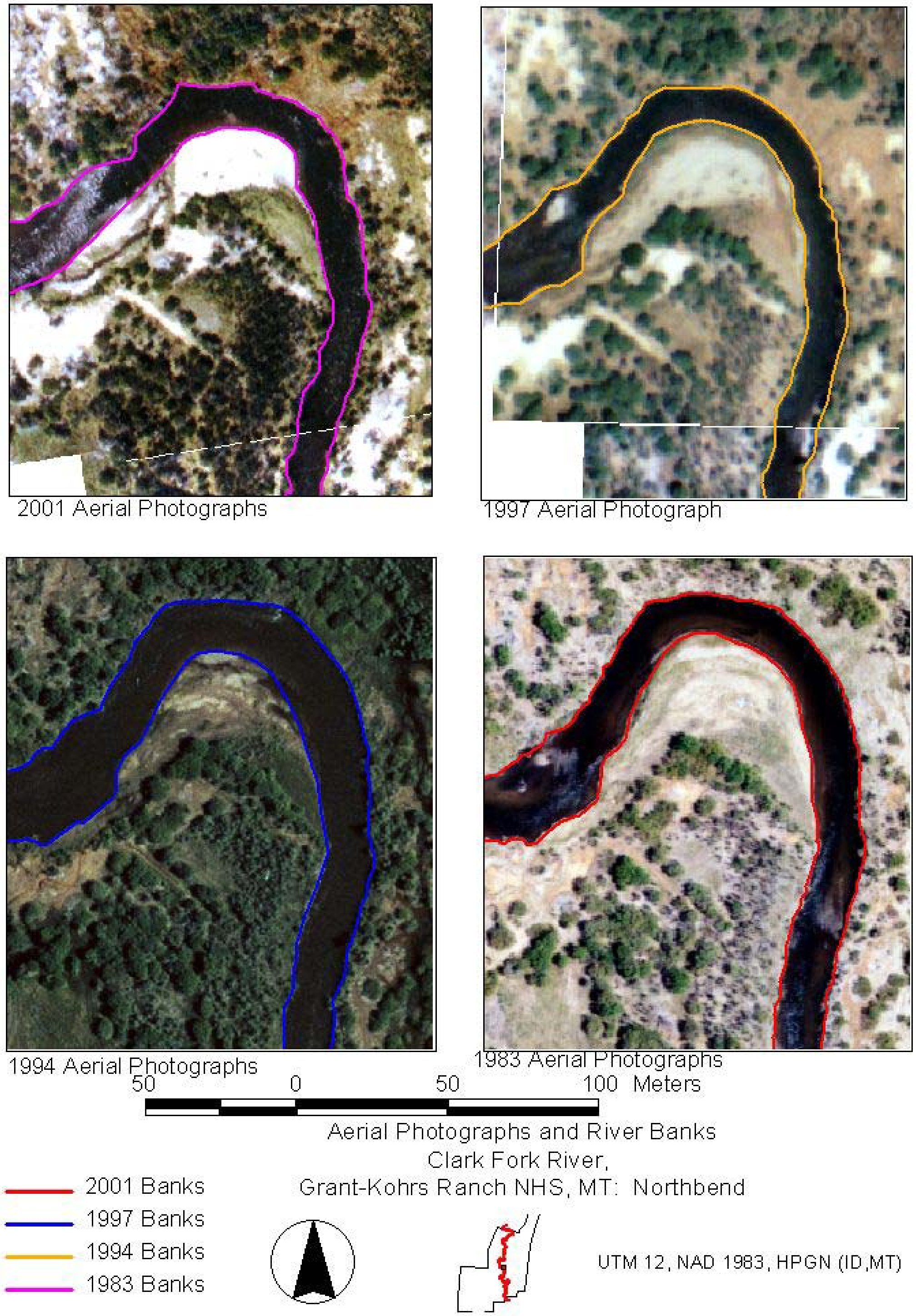
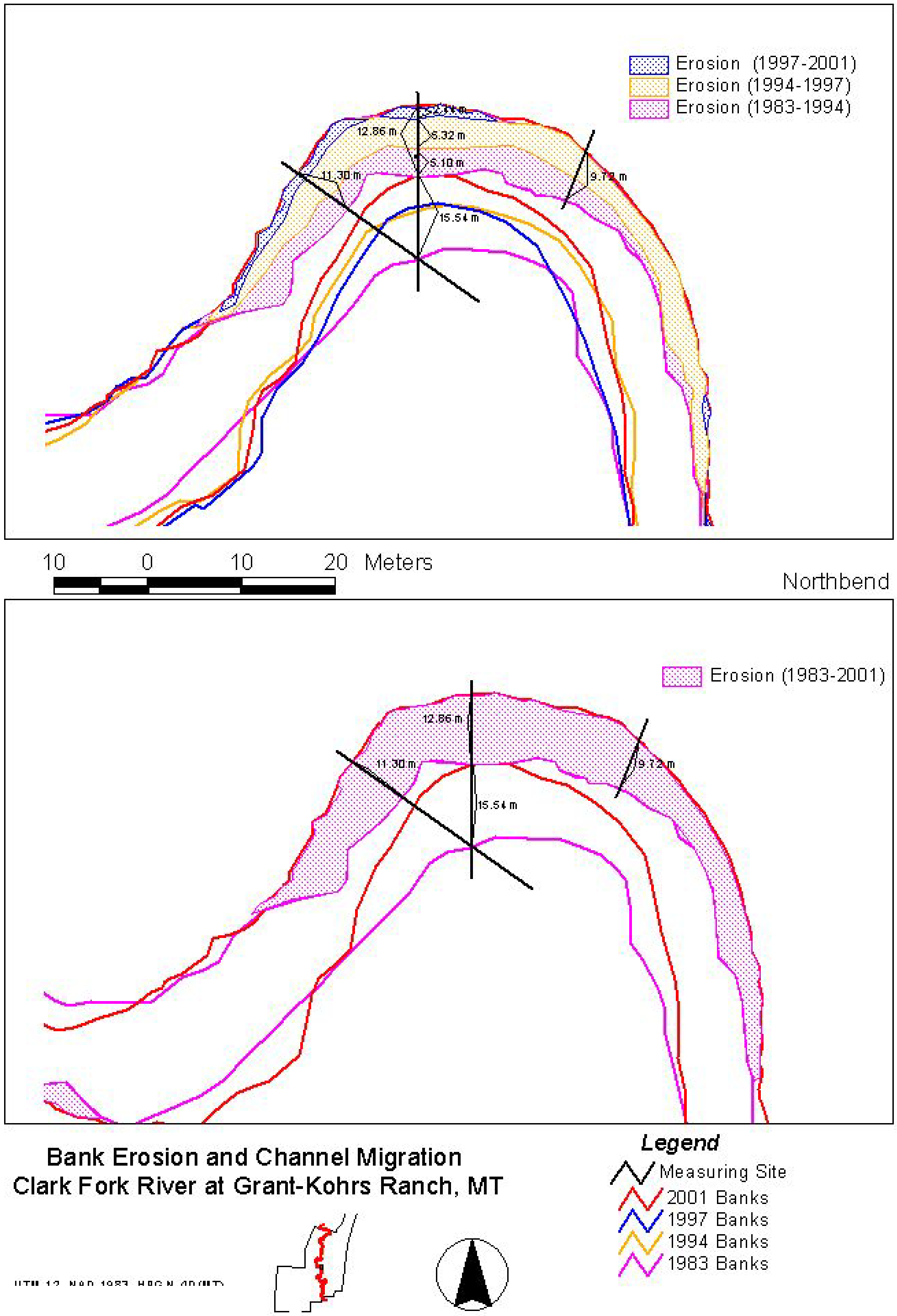

2001 Aerial Photographs
1997 Aerial Photograph
1994 Aerial Photographs
1983 Aerial Photographs
50 0 50 100 Meters
Aerial Photographs and River Banks
Clark Fork River,
Grant-Kohrs Ranch NHS, MT: Northbend
2001 Banks
1997 Banks
1994 Banks
1983 Banks
UTM 12, NAD 1983, HPGN (ID,MT)

Figure IV-14



Erosion (1997-2001)
Erosion (1994-1997)
Erosion (1983-1994)
12.86 m
6.32 m
5.10 m
11.30 m
9.72 m
15.54 m
10
0
10
20
Meters
Northbend
Erosion (1983-2001)
12.86 m
11.30 m
9.72 m
15.54 m
Bank Erosion and Channel Migration
Clark Fork River at Grant-Kohrs Ranch, MT
Legend
Measuring Site
2001 Banks
1997 Banks
1994 Banks
1983 Banks

Figure IV-15

Figure IV-16. Daily Discharge for the Clark Fork River at Deer Lodge, MT

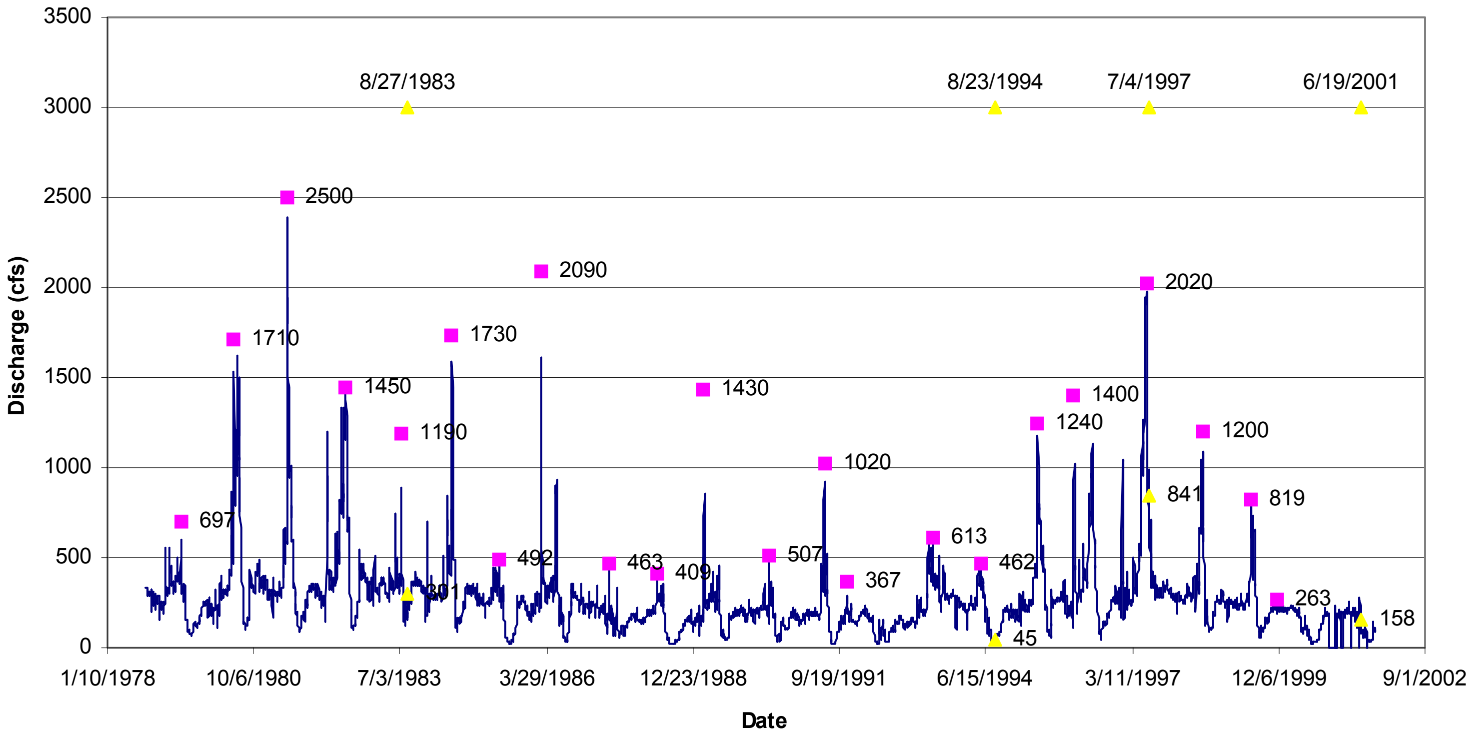
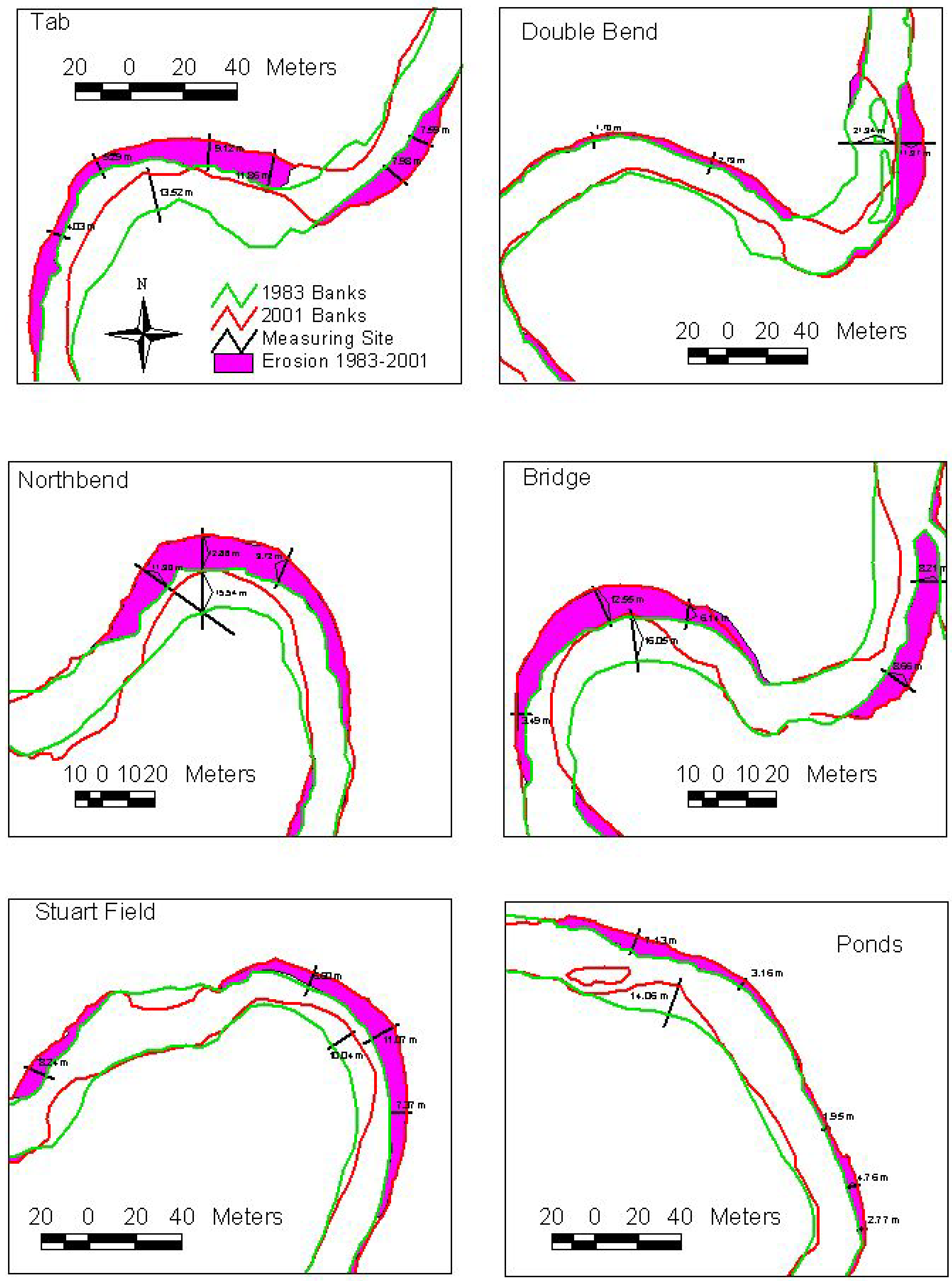


Figure IV-16



Examples of Bank Retreat
Clark Fork River at Grant-Kohrs NHS, MT

Figure IV-17

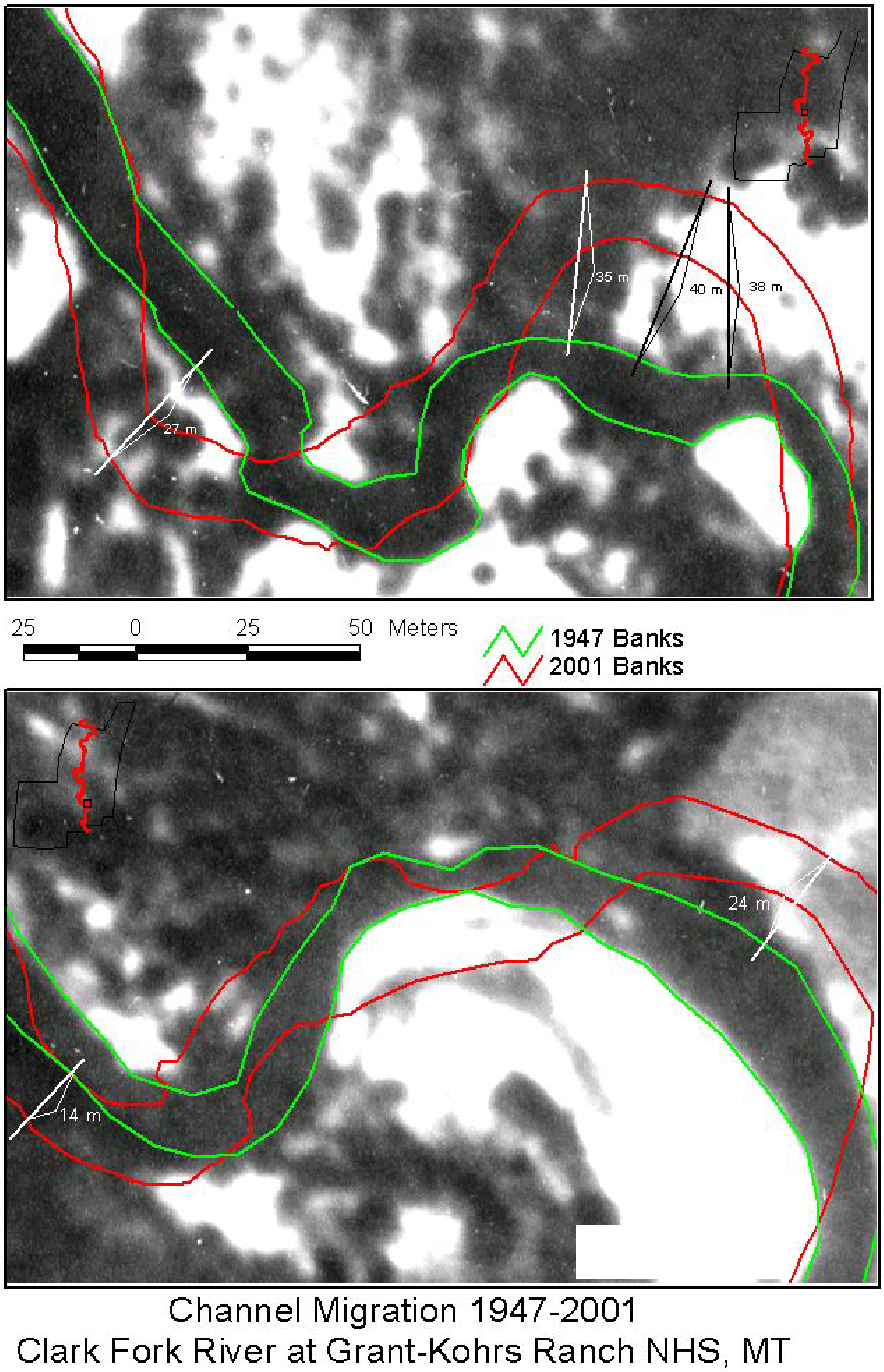

35 m
40 m
38 m
27 m
25 0 25 50 Meters
1947 Banks
2001 Banks
24 m
14 m
Channel Migration 1947-2001
Clark Fork River at Grant-Kohrs Ranch NHS, MT

Figure IV-18

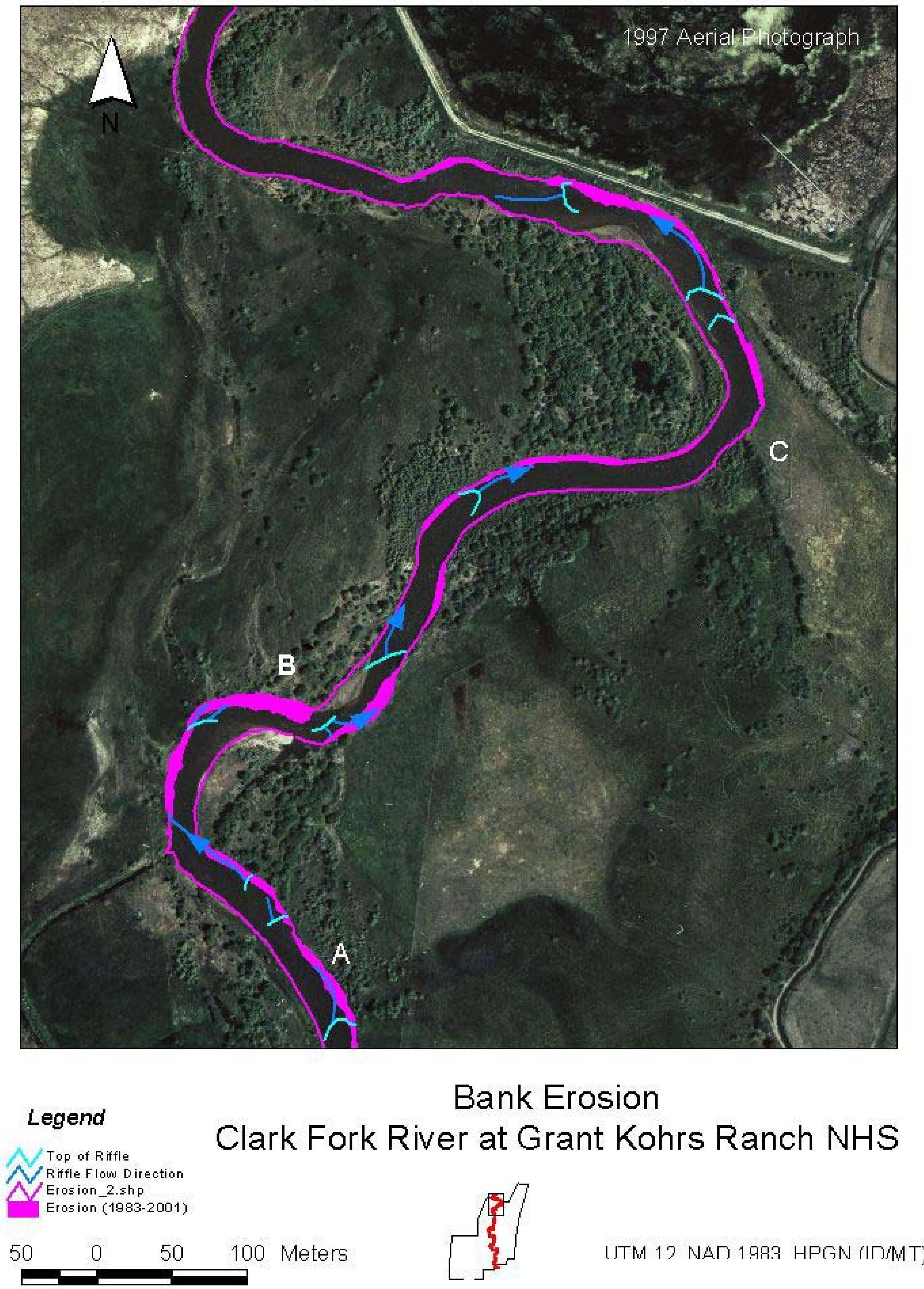


Figure IV-19a

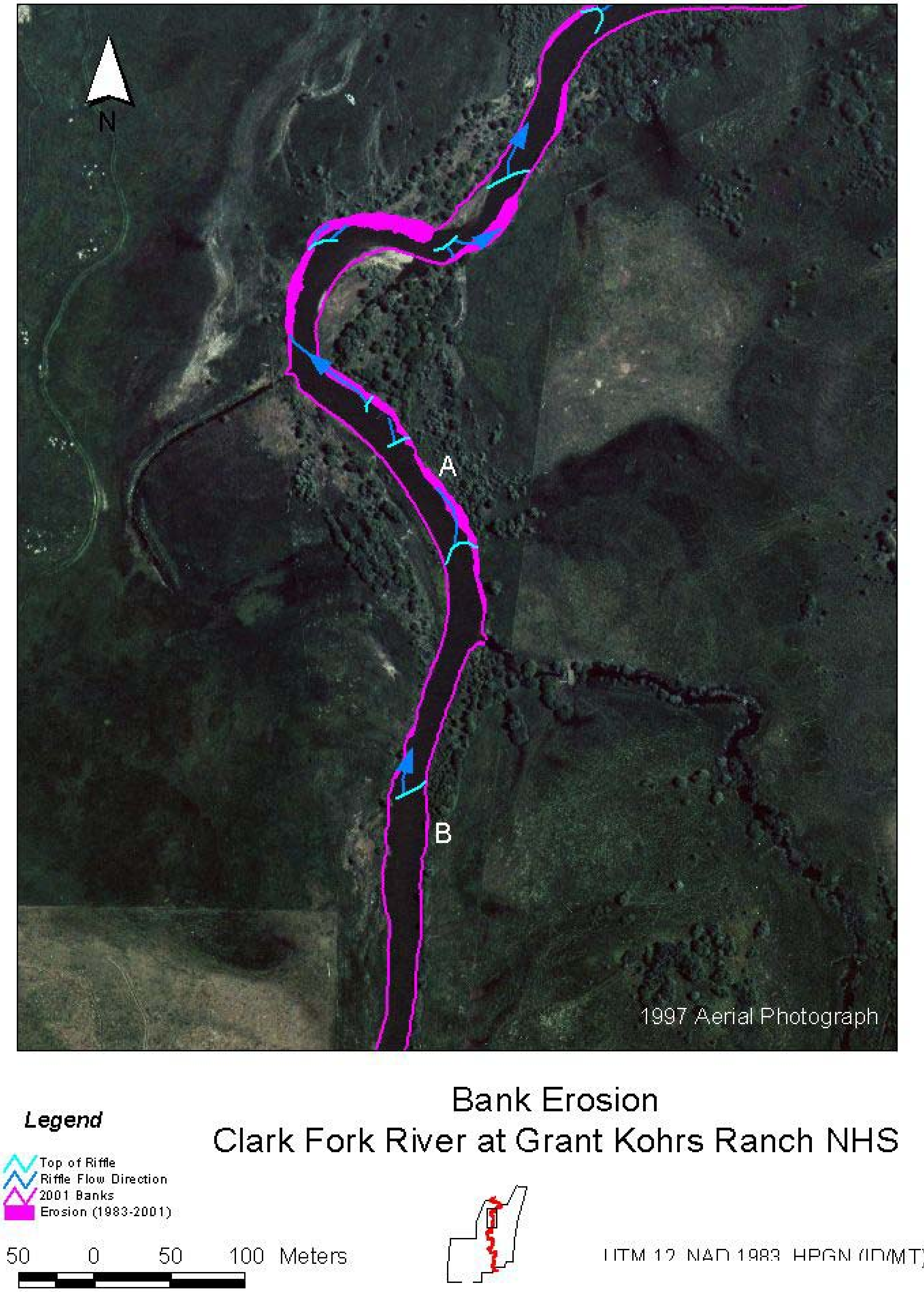


Figure IV-19b

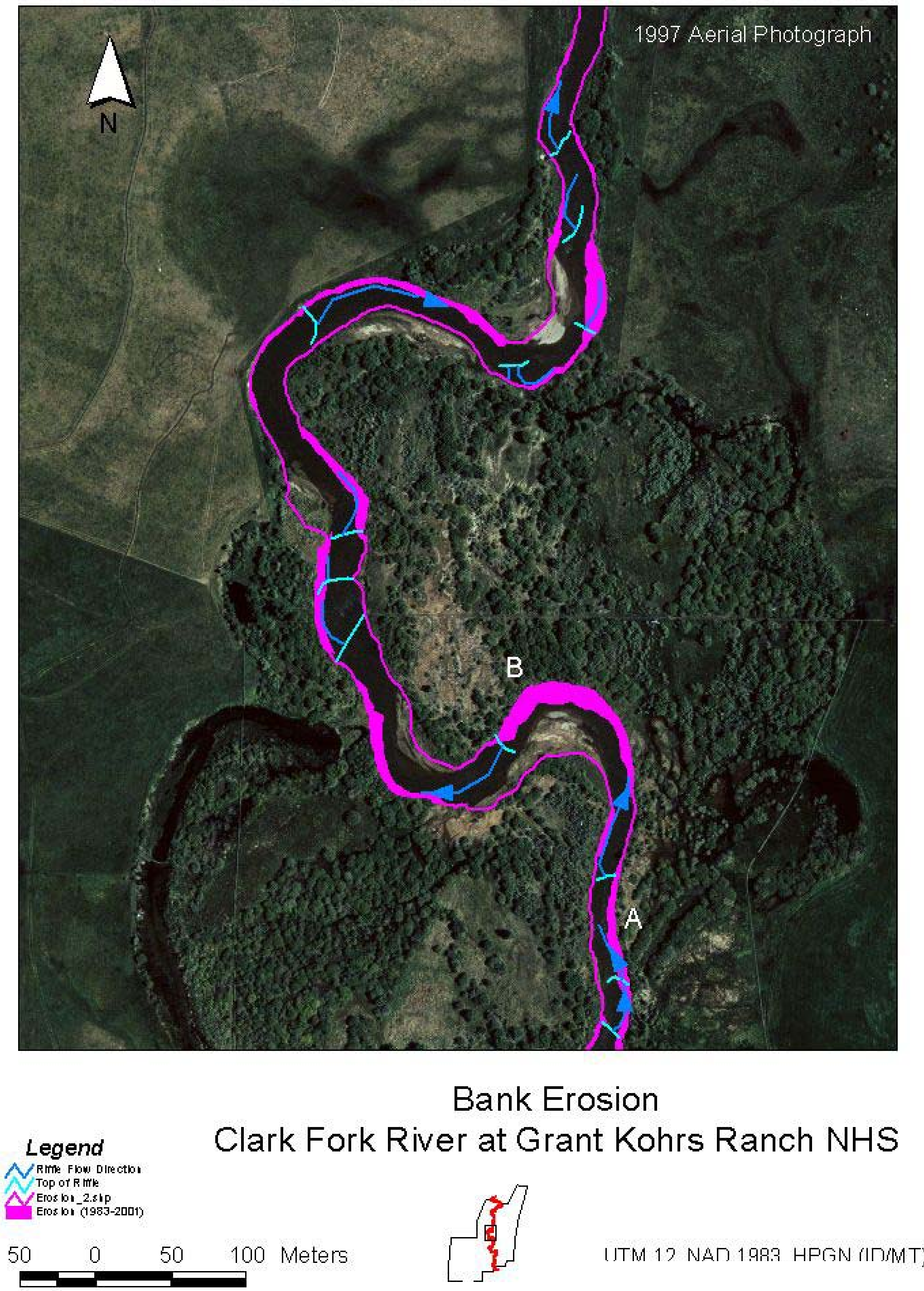


Figure IV-19c

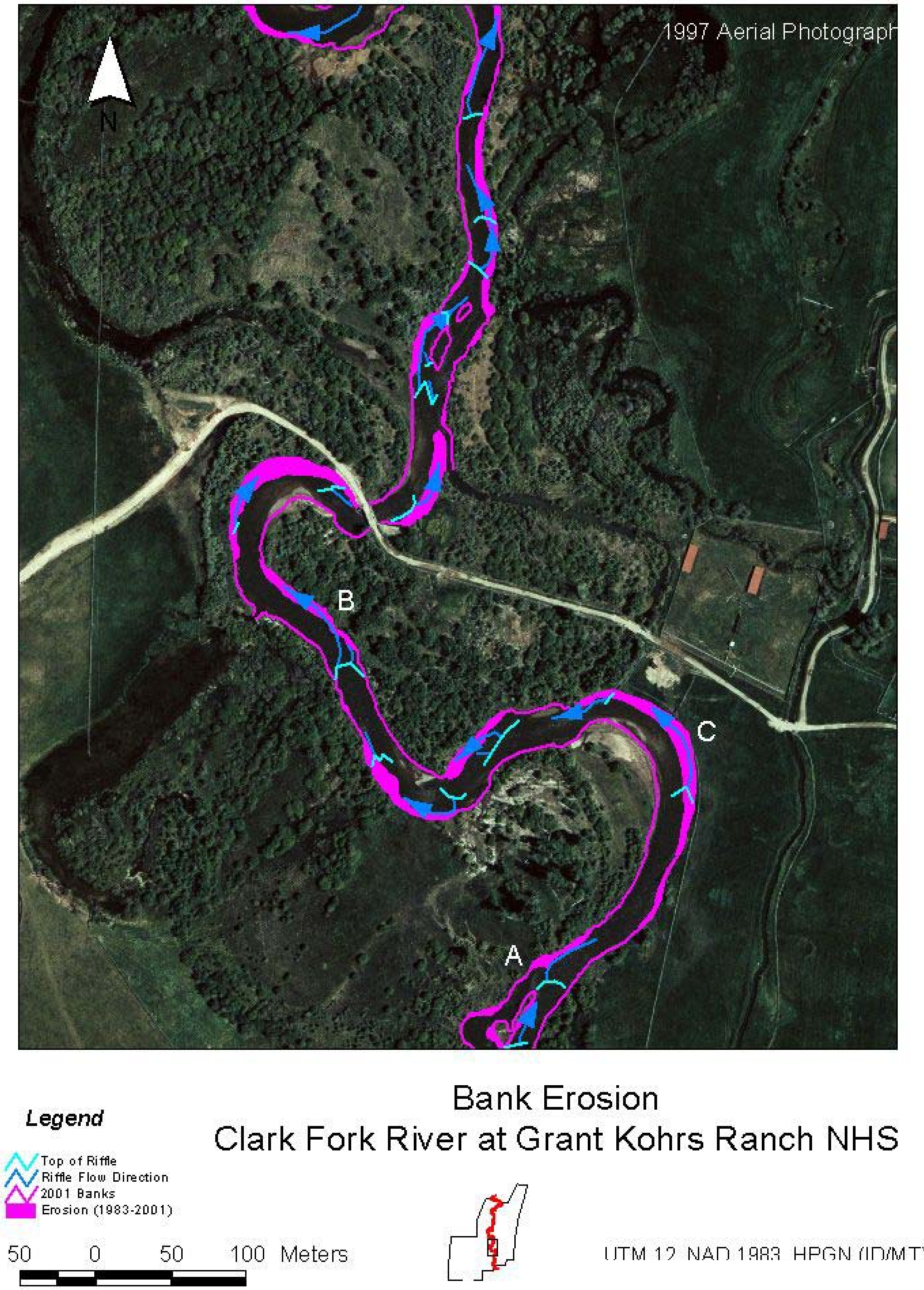


Figure IV-19d

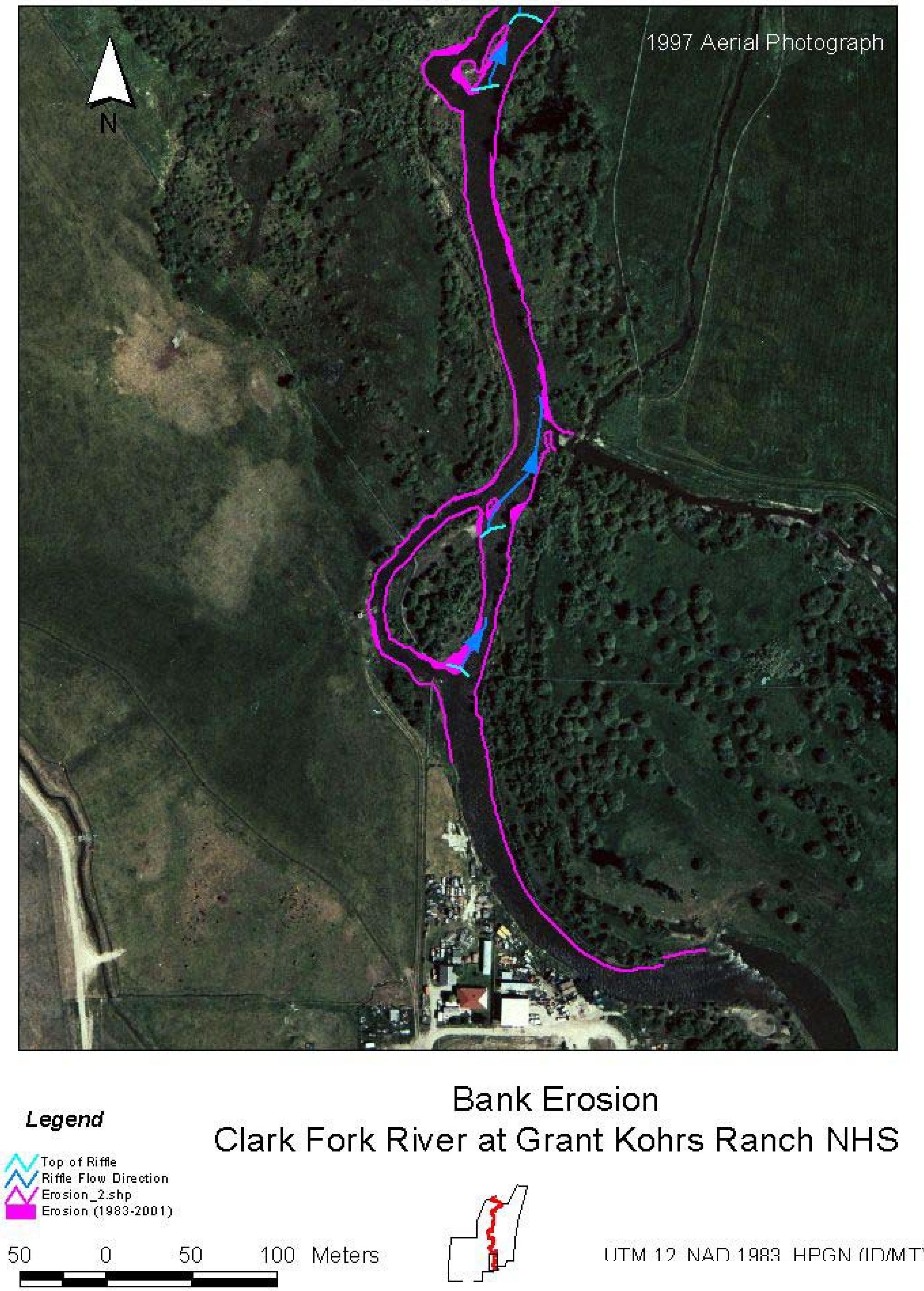

1997 Aerial Photograph
N
Bank Erosion
Clark Fork River at Grant Kohrs Ranch NHS
Legend
Top of Riffle
Riffle Flow Direction
Erosion_2.shp
Erosion (1983-2001)
50 0 50 100 Meters
UTM 12 NAD 1983 HPGN (ID/MT)

Figure IV-19

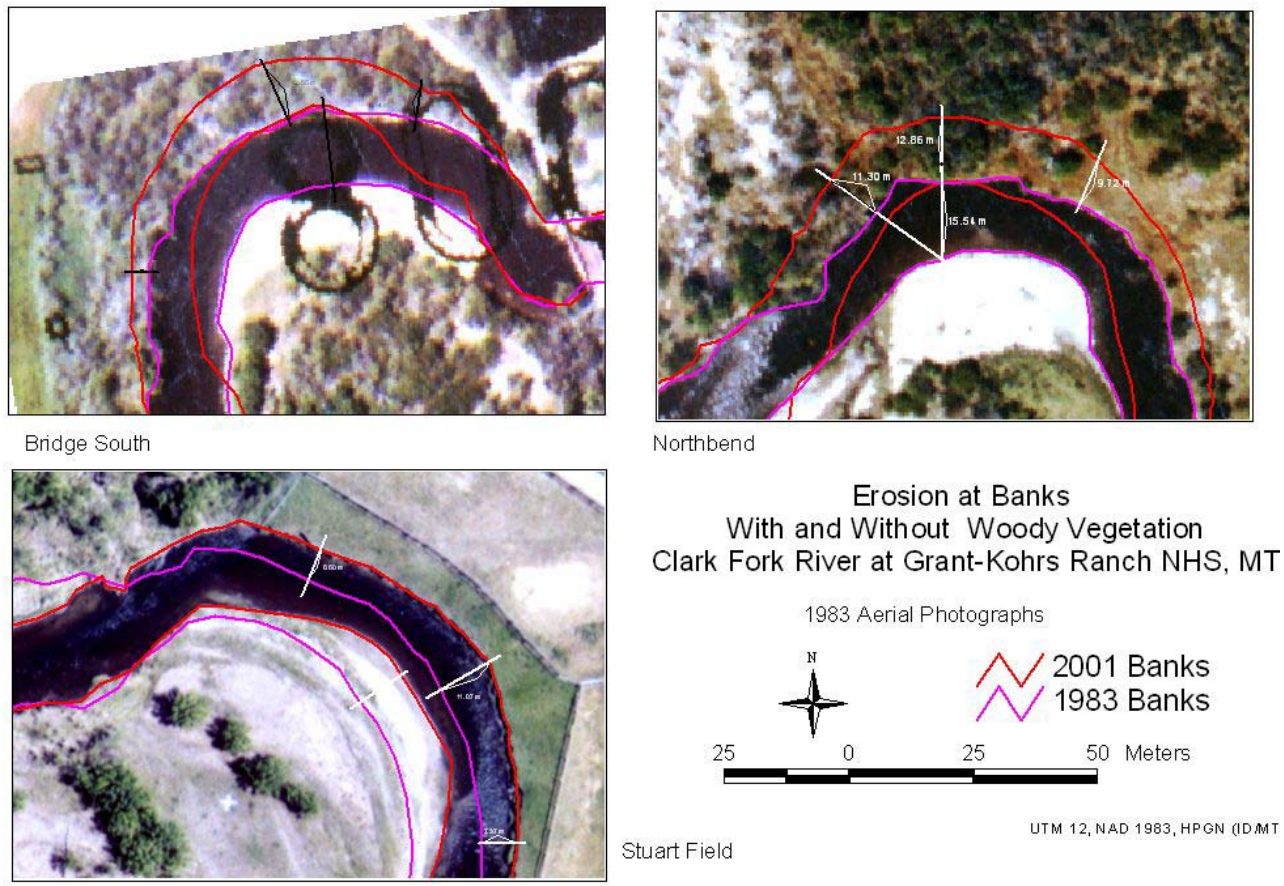
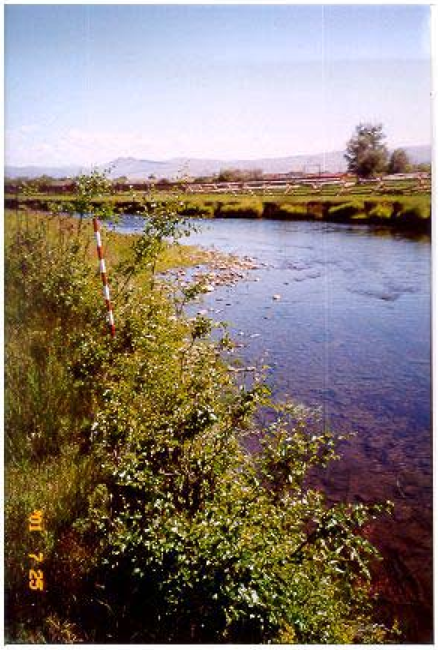

12.86 m
11.30 m
15.54 m
9.72 m
Bridge South
Northbend
Erosion at Banks
With and Without Woody Vegetation
Clark Fork River at Grant-Kohrs Ranch NHS, MT
1983 Aerial Photographs
N
2001 Banks
1983 Banks
25 0 25 50 Meters
UTM 12, NAD 1983, HPGN (ID/MT
Stuart Field

Figure IV-20

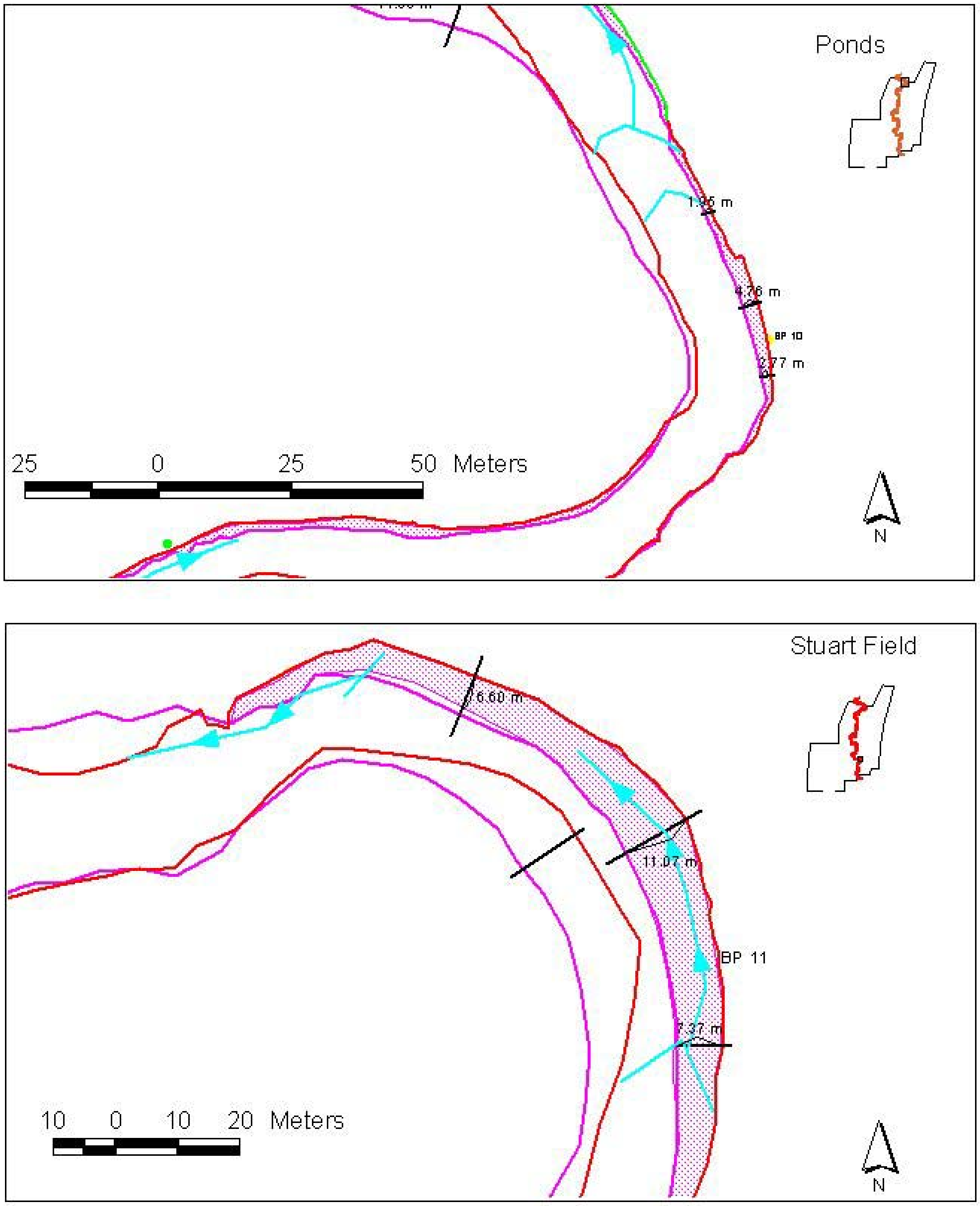
Figure IV-21



Short Shrubs Along Banks. Representativeof a large portion of the woody vegetation along the banks.

Not Much Root Structure in the Lower 2/3 of the Bank.

Figure IV-22

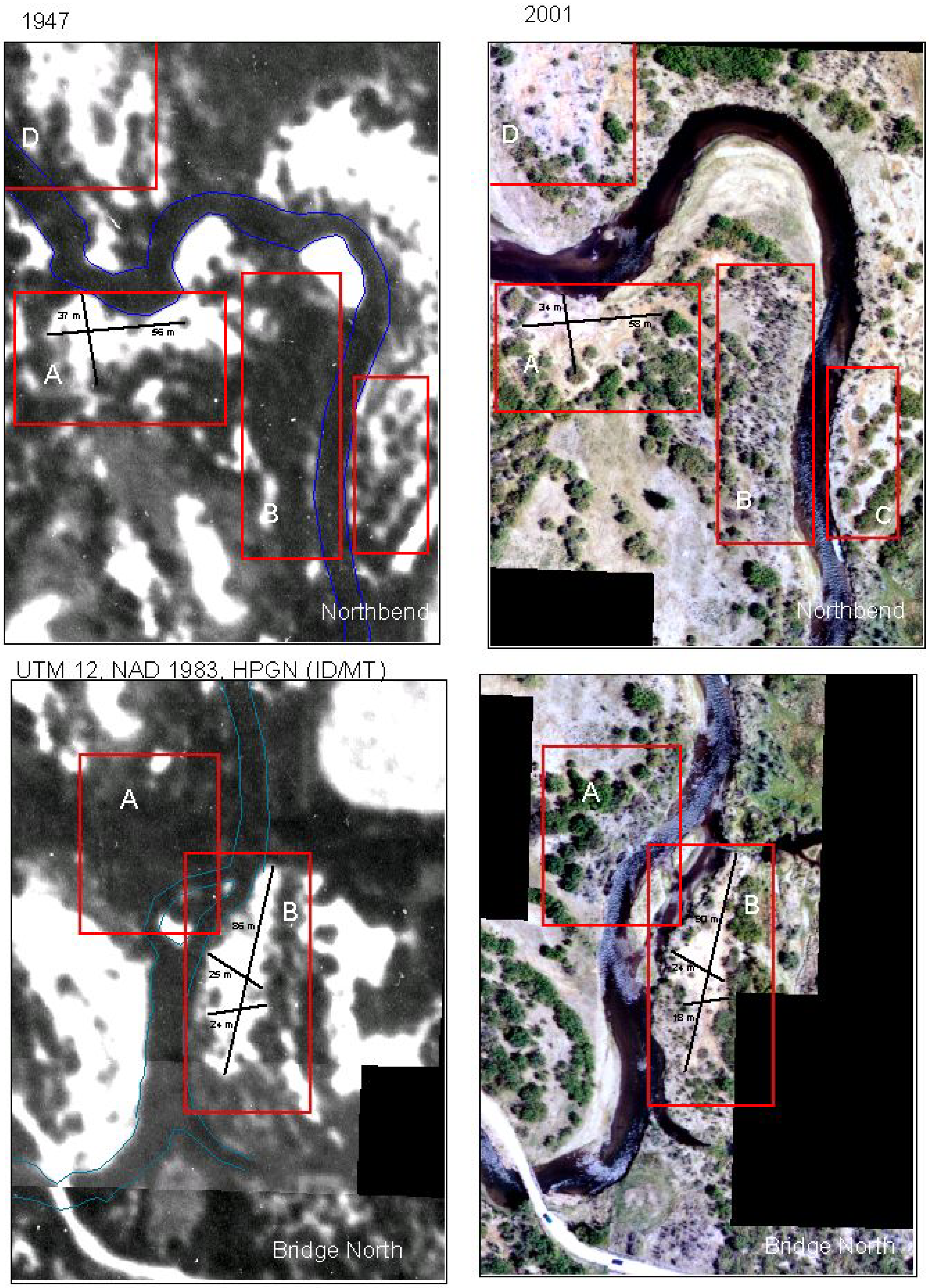


Comparison of Bank Erosion at Banks with and without Tailings
Clark Fork River at Grant-Kohrs Ranch NHS, MT

Legend

Riprap
2001 Banks
1983 Banks
Chemistry Profile Sampling Site
Erosion (1983-2001)
Erosion (1994-2001)
Erosion (1997-2001)
Riffle Flow Direction
Top of Riffle

Figure IV-23



Slickens Dynamics 1947-2001
Grant Kohrs Ranch NHS

Figure IV-24

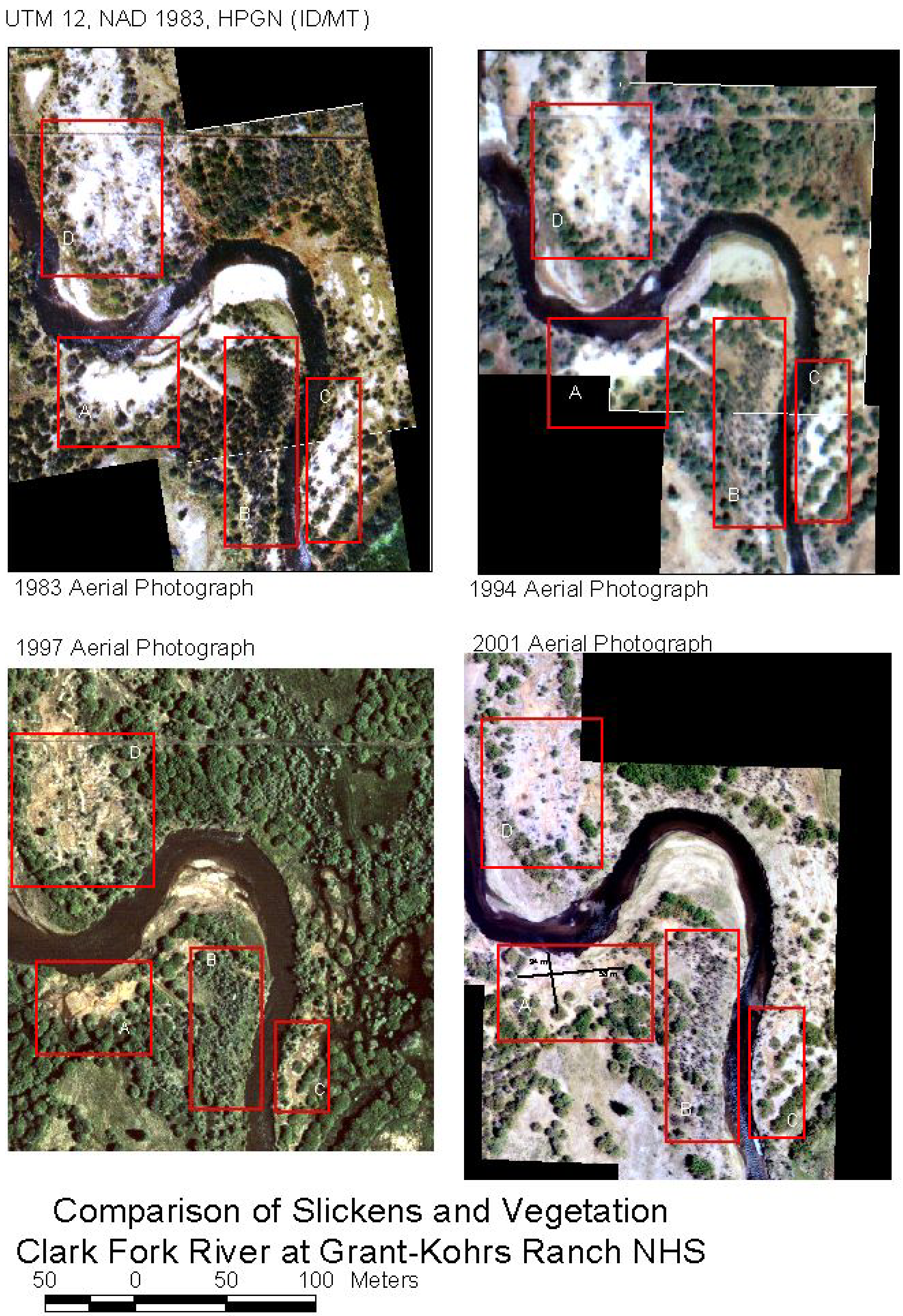
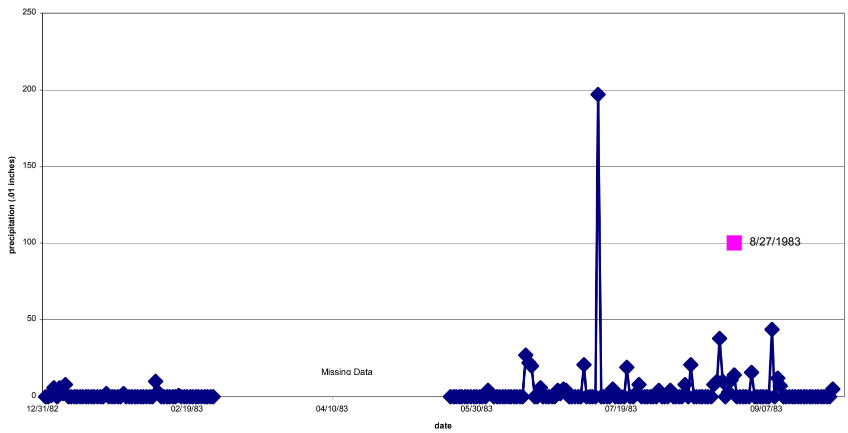


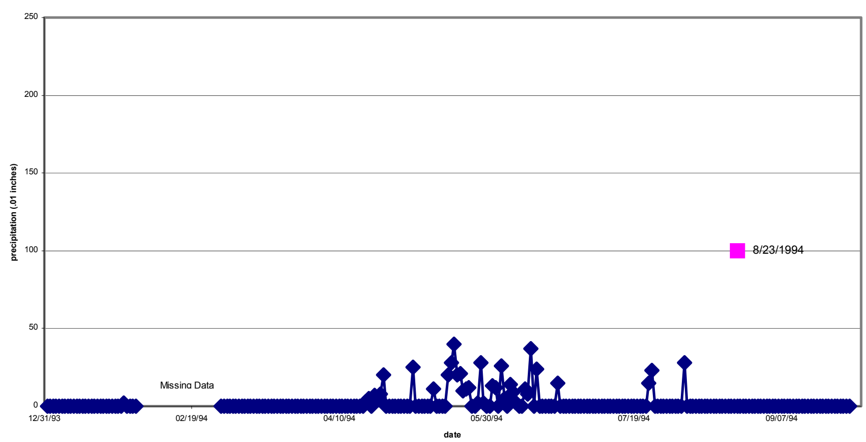
Figure IV-25

Figure IV-26. Precipitation in 1983, 1994, and 1997

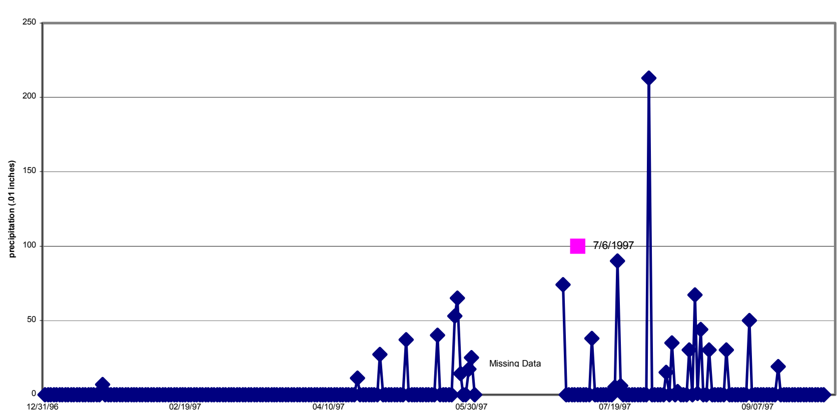
1983 Precipitation (Jan-Sept)



1994 precipitation (Jan-Sept)



1997 Precipitation (Jan-Sept)



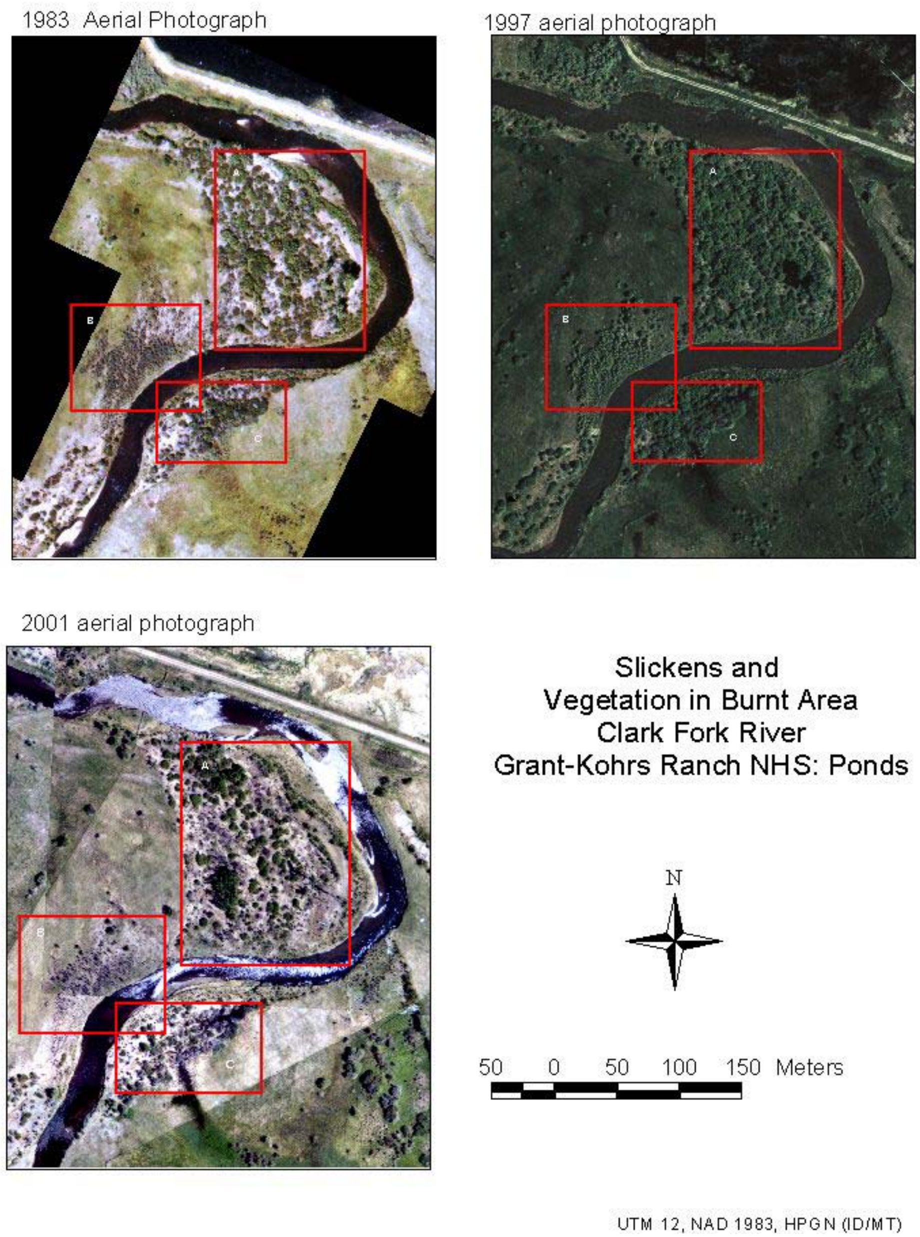

1983 Aerial Photograph
A
B
C
1997 aerial photograph
A
B
C
2001 aerial photograph
A
B
C
Slickens and
Vegetation in Burnt Area
Clark Fork River
Grant-Kohrs Ranch NHS: Ponds
N
50 0 50 100 150 Meters
UTM 12, NAD 1983, HPGN (ID/MT)

Figure IV-27